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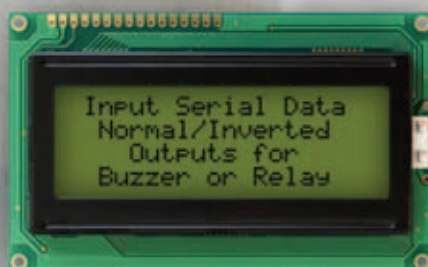
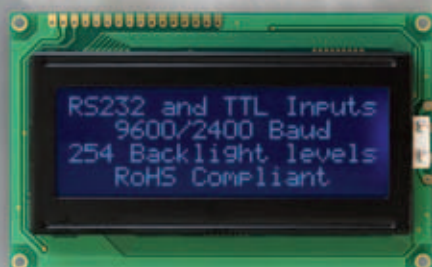
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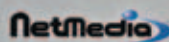


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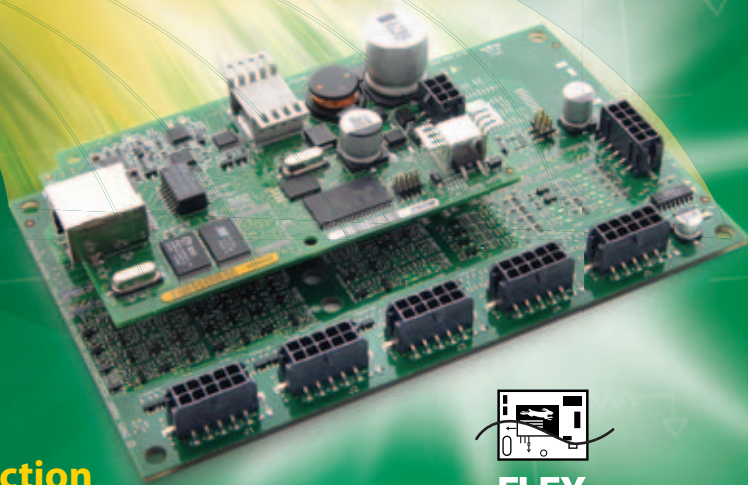
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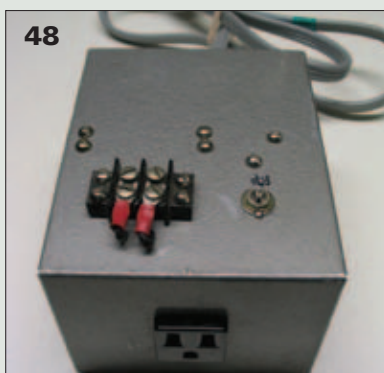
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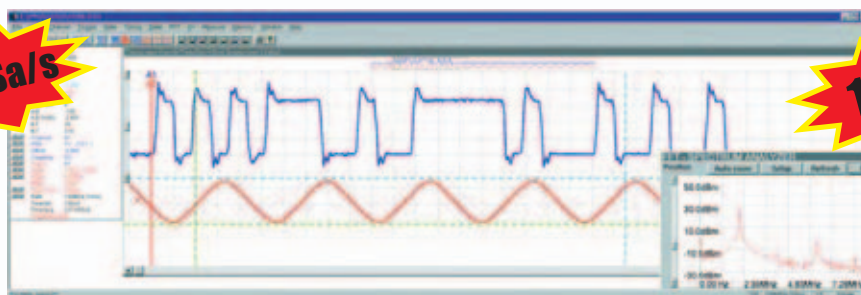
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READER FEEDBACK

NUTS AND VOLTS
EVERYTHING FOR ELECTRONICS

IN MEMORIAM TJ BYERS 5/11/47 - 1/10/07



For 13 years, TJ and I were partners in crime, adventure, and life — although there was a part of his life that stood outside our partnership, and that's the part that concerns you, his readers.

It started with rocket science. As a young engineer working for Hughes Aircraft, TJ contributed to Neal Armstrong's "one great step for mankind" walk on the moon. Hughes paid his tuition at UCLA, but just before that famous moonwalk, the company laid off its moonshot staff. TJ watched Neil Armstrong on TV at a reunion at a bar with his former co-workers.

He'd been ailing but misdiagnosed for years by doctors who thought he had mono. Still in his early 20s, with a young wife and infant son, he was finally diagnosed with terminal Hodgkin's Disease. He joined an experimental program of draconian chemotherapy and massive radiation.

In partial remission, he moved to Canyon Country, bought a biker bar, and built his own house from scratch on leased government land. He married his barmaid, 12 years his senior, and raised three of her four children, along with a young son of his own from his first marriage. (In those

days, divorced fathers rarely obtained custody, or wanted it.) He fed his family on the free-range ducks, squabs, pigs, and dairy goats that he raised lovingly on his own subsistence ranch. He suffered another bout of the disease and this time recovered fully, except for the future results of his "cure." One of a very few survivors of the harsh experimental treatment, it bought him another 35 years of life — and then death by the slow-acting radiation poisoning that seeded his lungs with fast-growing cancer.

When he left the bar business, he took up writing. Although his illness had forced him to drop out from UCLA a couple of semesters short of a degree (taking only the hard-science courses and skipping the language and social sciences requirements), he went on to write 12 published college-level engineering textbooks for a major educational publisher. He also wrote for numerous technical magazines and *Mother Earth News*. We met after he moved to my home-town of San Francisco, CA, to set up *PC World's*



TJ was 52 in this photo. Left to right: grandson Matthew, granddaughter Nicole, girlfriend Joan, TJ, grandson Chris. Taken at Thanksgiving dinner at TJ and Joan's flat in San Francisco shortly before moving to San Diego.

computer-testing laboratory. Then they offered him the job of managing the lab, but he didn't want to be anybody's boss, and returned to free-lance work. His then-wife hated San Francisco and left it and him. Soon after, we transited from a long-standing friendship to become a team for his final 13 years. He grew a beard, grew his hair

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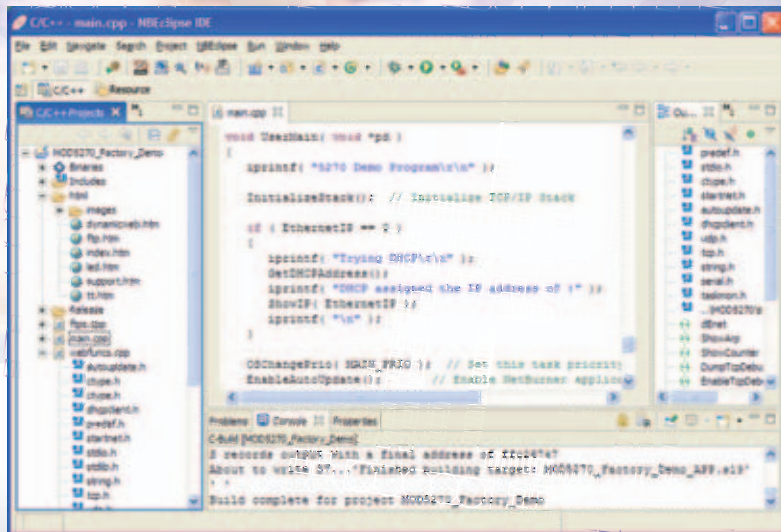
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■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

TRANSISTOR APPROACHES THz MILESTONE

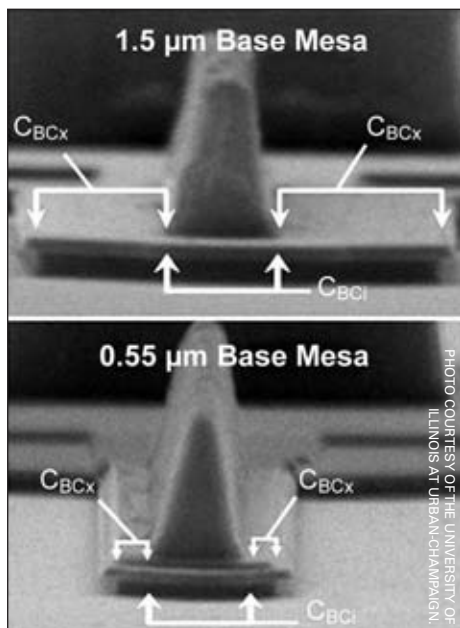


PHOTO COURTESY OF THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

■ Scanning electron microscope images of original base-collector mesa (top) and improved design (bottom).

With assistance from a couple grad students, Prof. Milton Feng of the University of Illinois at Urbana-Champaign (www.uiuc.edu) recently broke his own speed record for the world's fastest transistor. Operating at 845 GHz, the device is said to be approximately 300 GHz faster than anything else in the research world and approaches the goal of a 1 THz device. According to Feng, the indium phosphide/indium gallium arsenide device "utilizes a pseudomorphic grading of the base and collector regions. The compositional grading of these components enhances the electron velocity, hence reduces both current density and charging time."

In addition to the pseudomorphic construction, the device is enhanced by an improved fabrication method that

reduces real estate. A reduction in the device's vertical dimension reduces the distance the electrons have to travel, thus providing greater speed. And because the collector's lateral dimension is reduced, it can charge and discharge faster. At room temperature, the transistor operates at a mere 765 GHz, but when cooled down to -55°C, it jumps to 845 GHz. Work continues to improve the speed and to reduce the current density, which will reduce junction temperature and improve reliability.

CURE DEVELOPED FOR DINGY NANOTUBES

If the wife has been after you about the buckets of dirty nanotubes in the garage, a solution is here, courtesy of the National Institute of Standards and Technology (NIST, www.nist.gov). Apparently, researchers accidentally discovered it while looking for quantitative methods to evaluate laser damage to nanotube coatings for the next generation of standards for optical power measurements. Carbon nanotubes have great promise as electrical wiring in molecular devices, hydrogen storage components in fuel cells, and just as very strong fibers, but better methods have been needed for purifying the raw nanotube materials. The new technique

zaps the nanotubes with carefully calibrated laser pulses, reducing the levels of contaminants such as soot, graphite, and others. Fortuitously, it is also cheaper and more effective than conventional wet chemistry processes.

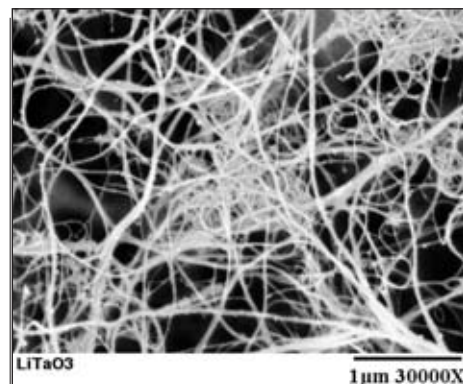
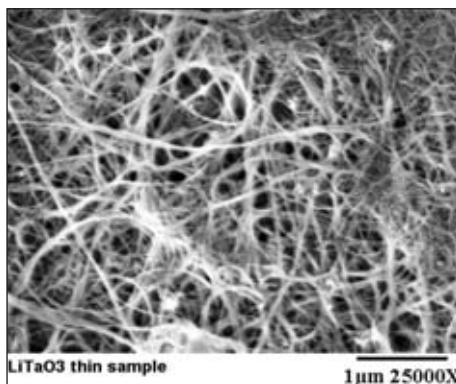
In operation, the laser transfers energy to the vibrations and rotations in carbon molecules in both nanotubes and contaminants, but because the tubes are more stable, the impurities soak up most of the energy and are eliminated in a reaction with oxygen and ozone in the surrounding air. As shown in the before and after photos below, the nanotubes look blacker after treatment, suggesting less graphitic material and an increase in porosity. The responsivity of a prototype material increased five percent after the nanotube coating was cleaned.

COMPUTERS AND NETWORKING

SYSTEM INCORPORATES PHONES AND MUSIC

Rolling with the trend toward universal connectivity, Ford Motor Company (www.ford.com) and Microsoft (www.microsoft.com) recently announced the Sync™ product, a factory-installed communications and

■ Before and after electron microscope images of a pyroelectric detector coated with single-walled nanotubes (SWNTs). PHOTOS COURTESY OF NIST.





entertainment system that will be available in 2008 models of various Ford, Mercury, and Lincoln autos. Basically, Sync will allow you to operate nearly any mobile telephone or digital media player in your vehicle via voice command or the steering wheel or radio controls.

Among the features are voice-activated calling, text messages that are converted to audio and “spoken” for you, voice-activated dialing, voice recognition capabilities, “multilingual intelligence” (i.e., fluent in English, French, and Spanish), and support for as many as 12 different phones. Supported music players include iPods®, Zunes™, and most USB drives using MP3, AAC, WMA, WAV, and PCM formats, and you can stream music to the car’s sound system from a Bluetooth-enabled device.

No price tag has been attached to the system yet, although rumor has it that it will be something less than \$1,000, and perhaps significantly less. For details, visit www.syncmyride.com.

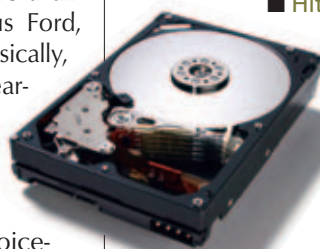
TURN YOUR CAR INTO A HOT SPOT

Also addressing the needs of folks who live in their cars (figuratively or otherwise) is Autonet Mobile (www.autonetmobile.com), billed as the first Internet service provider for cars. The company’s wireless broadband network device allows passengers to check email, surf the web, play games, or communicate via any WiFi-enabled device, and it is said to work on 95 percent of US roads, regardless of driving conditions or location. You just plug the unit into a cigarette lighter or standard wall plug, and it’s ready. Operation is enhanced by Autonet’s

■ **Presentation of the Ford Sync™** system, designed to change the way consumers use digital media players and mobile phones in their vehicles.

patent-pending “TRU Technology,” which provides session management between high- and low-speed networks for more reliable service. The device will set you back \$399, and the monthly service charge is \$49.

HARD DRIVE STORES 1 TB



■ **Hitachi’s new DS7K1000** (descended from the DS7K500 shown) is offered as the industry’s first 1 TB device.

PHOTO COURTESY OF HITACHI.

If you’ve been short on storage space for video, photos, music, and other byte-intensive files, you may welcome the new Deskstar® 7K1000 from Hitachi Global Storage Technologies (www.hitachigst.com). Said to be the industry’s first 1 TB hard drive, it should be available by the time this goes to press or shortly thereafter. The 3.5-in, 7,200 RPM drive offers some nice features, including three low-power idle modes to boost power efficiency, adaptive error recovery, and “bedroom quiet” acoustics (assuming you use it in the bedroom for some reason).

But the main claim to fame is capacity, equivalent to nearly 250 hours of HD video programming, which will allow you to lose truly amazing amounts of data if it ever crashes. The suggested retail price is \$399, which is a mere \$0.40 per gigabyte.

FREE INTERNET APPLICATION SUITE

It was recently reported that Mozilla’s Firefox browser jumped in popularity by 46 percent in 2006 and is now used by 14 percent of all computers. (During the same period, Internet Explorer’s market share dropped from 85.1 percent to 79.6 percent, in spite of the release of a new version.) Firefox users may recall that the Mozilla Foundation once offered a complete Internet application package called the Mozilla Application Suite

but dropped development of the all-in-one product to focus on Firefox and the Thunderbird email client. However, a group of people in the Mozilla community have resurrected it in the form of the SeaMonkey Project.

SeaMonkey is basically a combination web browser, email, and newsgroup client, IRC chat client, and HTML editor in one package, and it is available free for Windows, Linux, and Mac operating systems. You can learn more about it, download the latest version, and even get involved in the project by visiting www.mozilla.org/projects/seamoney/.

CIRCUITS AND DEVICES

COMIC ORGANIZER DEVELOPED



PHOTO COURTESY OF INTELLISCANNER CORP.

■ **IntelliScanner Comic Collector**, its personal barcode scanner and companion software package for automatic comic collection management.

Let’s say you’re a truly pathetic nerd who still lives with his parents and has built his world around gillions of comic books piled so high that nothing but an occasional silverfish can penetrate them. Well, believe it or not, the folks at IntelliScanner Corp. (www.intelliscanner.com) have been thinking of you. Earlier this year, they introduced IntelliScanner Comic Collector, a personal comic organization system that automatically identifies issues and organizes your collection with barcode technology.

Designed for both PCs and Macs, Comic Collector automatically pulls up detailed information and artwork for each series and issue and allows you to sort, organize, inventory, categorize, and share comic details with fellow geeks around the world. All you have to do is log onto www.intelliscanner.net to make the connection.



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■ Construction of the EDL supercapacitor.

The system also generates comic tags that can be printed on an inkjet or laser printer, providing barcode-enabled inserts for any bagged comic. No pricing information is available as of this writing, but the product is scheduled to ship in April.

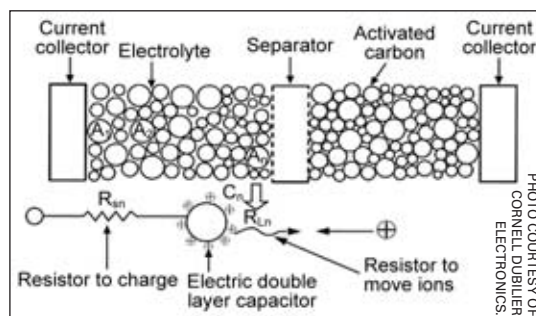


PHOTO COURTESY OF
CORNELL DUBILIER
ELECTRONICS

CAPACITOR DESIGNED FOR BATTERY BACKUP

Among the latest from Cornell Dubilier Electronics (www.cde.com) is the electronic double layer (EDL) supercapacitor, designed for use in battery backup applications where memory hold-up is required during battery replacement. Available in horizontal and vertical radial leaded stacked coin configurations, a cylindrical case with radial leads, and a surface mountable package, the capacitance ranges from 0.22 to 70 Farads with a voltage range of 2.1 to 5.5 VDC, depending on the value. The components are said to provide unlimited charge and discharge capability, a 15-year operating life, and battery life extension of up to 160 percent, and no recycling is necessary. Typical applications include cellular phones, solar battery back-up, small motor starters, gaming machines,

and clock battery backup. The price ranges from about \$0.50 to \$5 per unit.

WORLD'S BRIGHTEST LED

Among the latest developments in LED technology is the P4, from Seoul Semiconductor (www.zled.com). The device is said to be the world's brightest, emitting 240 lm at 1A and giving 100 lm/W at 350 mA. The company uses patented phosphor and packaging technologies to boost luminous flux and improve reliability, allowing it to be used in various lighting applications and industries, including street lights, decorative and architectural lighting, and general illumination. There is also a version with 80 lm at 350 mA. The company is projecting that upcoming improvements will boost the P4's luminous efficiency to 135 lm/W this year and 145 lm/W by the first quarter of 2008. **NV**



■ The P4 LED provides 240 lumens from a single-die light source.

INDUSTRY AND THE PROFESSION

IEEE OFFERS INTERNET TV

The Institute of Electrical and Electronics Engineers (IEEE, www.ieee.org) has launched a series of Internet broadcasts covering various areas of technology and engineering. Some of the programming is available only to IEEE members, but others are free to the general public, offering information and guidance about careers in technology and engineering, topics of public interest, and introductions to new IEEE products. Currently, a 21 minute public program focuses on careers in information technology and draws on the experiences of IT professionals from both large

and small companies. New programming will be introduced monthly and is available in both Windows Media Player and Real Player formats. To check out the latest offerings, visit www.ieee.org/web/membership/IEEEtv/about.html.

ONLINE SPENDING JUMPS

According to a report from comScore Networks (www.comscore.com), e-commerce for the 2006 Christmas holiday season (Nov. 1 to Dec. 31) reached \$24.6 billion, a 24 percent increase from 2005. The no. 1 day was Dec. 13, in which vendors racked up \$667 million in sales. For the full year, sales totaled \$102.1 billion, passing the \$100 billion mark for the first time. This represented a 24 percent increase from 2005, in which surfers spent \$82.3 billion.

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GETTING STARTED WITH PICs

THE LATEST IN PROGRAMMING MICROCONTROLLERS

■ BY CHUCK HELLEBUYCK

IN-CIRCUIT SERIAL PROGRAMMING

READER FEEDBACK IS SO IMPORTANT TO ME because without it, I'm writing in a vacuum. Just because I think a particular topic is interesting, doesn't mean the readers will. I've also seen a lot of emails from new visitors to the column and they want to see some of the topics I've already covered. One topic seems to come up often in reader feedback and that is the subject of In-Circuit Serial Programming (ICSP). This can be a very useful feature, so I thought I would cover it in detail this month.

The advantage to ICSP is the ability to program the PIC in-circuit. Now this may sound familiar since this is the same feature I've promoted about using a bootloader in a previous column. ICSP and bootloaders are similar in function, but the difference is the type of hardware support required. Bootloaders use an RS-232 or USB interface circuit between the PIC and a PC serial port connection. ICSP uses a PIC hardware programmer between the PIC and the PC. In fact, many PIC programmers use ICSP to program the PIC, even if you are putting the PIC in a socket.

My EZPIC programmer with the ic-prog.com software does this. The steps you need to make a PIC design in-circuit programmable so you don't have to remove the PIC are actually quite easy. The best part is it will

work with almost all PICs, while a bootloader typically won't work with the smaller ones unless you make your own custom version for each particular PIC family.

The biggest hang-up I've run into with readers who've tried ICSP is the serial communication signal gets affected by the circuitry connected to the PIC. For example, to program a PIC in-circuit using ICSP, you need five connections: 5V (Vdd pin), Ground (Vss pin), Vpp (MCLR pin), Data (PGD pin), and Clock (PGC pin). Many PIC programmers have these pins available on some kind of header, so the hardest part is making a conversion cable from your programmer to your circuit or circuit board. If the Clock or Data pins are not able to send the correct signal, the PIC will not program properly and you will get a verify error. This can easily be corrected.

Before I get into that I wanted to re-introduce one of the USB programmers I mentioned in the October '06 article which is the PICKit 2 programmer designed by Microchip. This programmer comes as a complete package for

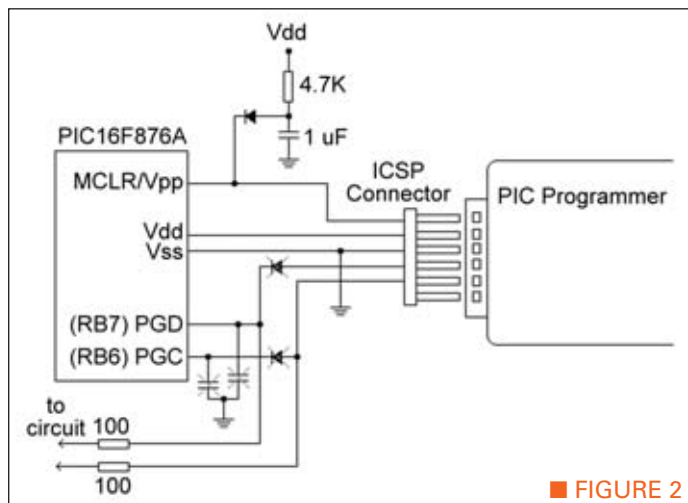
under \$50 from microchipdirect.com and it is designed to easily plug into a six-pin ICSP header. Five of those six header pins are the five ICSP connections I mentioned above. Figure 1 shows the PICKit2 package. It's small and USB-powered, so this makes a great programmer to place between the PC and your circuit for everything I'm about to talk about. I'll also show you a great ICSP feature of this programmer, but first let's cover the hardware requirements for ICSP.

HARDWARE FOR ICSP

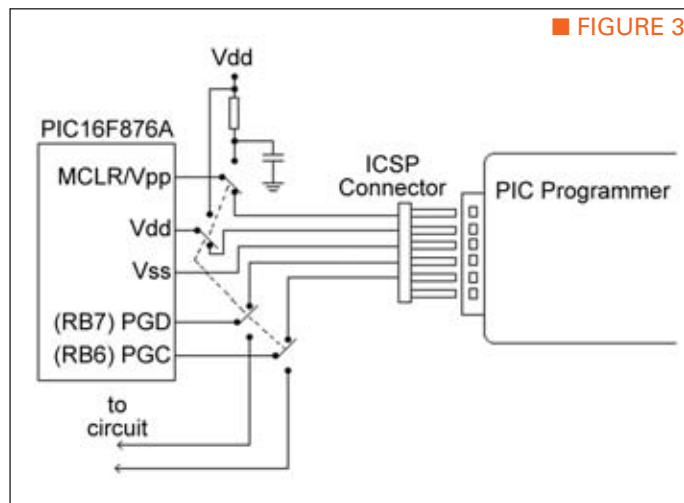
The schematic in Figure 2 shows the five ICSP connections and all the possible connection issues to watch out for in your design. Because of the way the ICSP feature works, you don't want to add any capacitance to the programming connections since this can delay the signals. Even the capacitance on the Vdd line should be monitored per the PIC programming specifications. The PIC programmer actually cycles the Vdd line off and on while sending the Vpp signal to the MCLR pin. This is done to put the PIC in programming mode. If there is too much capacitance, it may slow the signal down and not meet the

■ FIGURE 1





■ FIGURE 2



■ FIGURE 3

programming specs. You can get the programming specs for any PIC at the **Microchip.com** website.

You also don't want to load down the clock or data signal. The components that are crossed out show what not to include in your circuit. The diodes on the Data and Clock lines are a mistake because there is two-way communication when programming and verifying the part. It's pretty easy to see why they should not be included in your design.

What isn't quite so clear is the diode between the MCLR reset circuit and the MCLR/Vpp pin. This is recommended because the PIC programmer sends a high voltage signal to the Vpp line of around 12V-13.5V for a period of time. You don't want that signal feeding into your Vdd regulator. This is actually just a safety precaution though, because the current is small and the MCLR pull-up resistor will knock it down to prevent any damage. I use a 4.7K, but a 1K will work fine.

Another recommendation which is often missed is the series resistors on the PGD and PGC lines between the PIC and the rest of the circuit. These isolate your circuit from the PGD and PGC signals so your circuit doesn't load down the PIC programmer. This is usually where people have a problem with ICSP; 100 ohm resistors should not affect your circuit function but it should be plenty of resistance to isolate the programmer.

Another approach to ICSP isolation is to add a switch to your circuit. This is the way I handled it on the

original version of my Zipper board. A long time ago when I was just getting started with PICBasic, I wanted a simple BASIC Stamp-like module to program. The Zipper was the result. I didn't know about the clock and data series resistance idea or the MCLR diode suggestion because I didn't read all of the data sheet information. Before I added the switch, I could not get ICSP to work properly. I used the microEngineering Labs (www.melabs.com) EPIC programmer back then, but I tested ICSP with several PIC programmers and had inconsistent results. My solution was to use a smaller 100 ohm MCLR pull-up and that seemed to help on some programmers that created their Vpp voltage using a voltage divider arrangement. It still wasn't good enough though.

I then tried a four pole switch that allowed me to disconnect the PGC, PGD, Vdd, and MCLR pins from my circuit during programming to prevent it from loading down the clock and data and eliminate the MCLR resistor from the programming connection. Figure 3 shows the schematic for that type of arrangement. This worked very well and it's what I ended up doing with the Zipper.

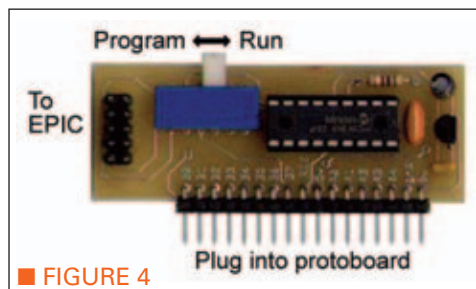
Figure 4 shows the finished original Zipper design with the ICSP header setup for the microEngineering Labs EPIC PIC Programmer which was very popular back then. It's still one of the best parallel port programmers available.

To use the Zipper, I would just slide the switch to program position

to download code and then slide it back to run the code. Eventually, I replaced the EPIC header with a six-pin SIP header to match the Olimex PG1 programmer that is a surface-mount version similar to my EZPIC programmer. This way, I could include a PIC programmer with the module for a lower price. I'm slowly phasing out that design as I use the Ultimate OEM bootloaders more than anything else now, but this is another option for successful ICSP.

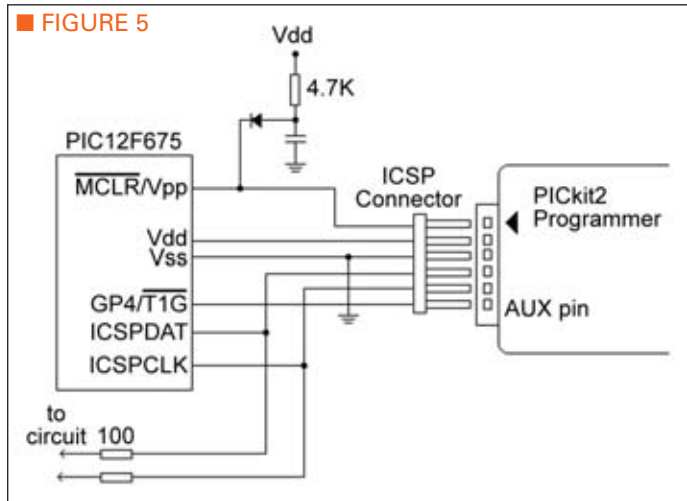
12F675 TRICK

Now this next section should be worth the price of your subscription. While playing with the PICkit2 programmer from Microchip, I actually read the manual. (No really, I did.) It details that the sixth pin on the PICkit2 ICSP connector — also known as the AUX pin — can be used to regenerate the internal oscillator calibration OSCCAL value that is set at the factory and placed in the last location of program memory. Remember, I talked about how that value could be erased if you erase the whole PIC 12F675 chip back in the January article? Well, if you tie the AUX pin to the GP4/T1G pin of the 12F675



■ FIGURE 4

■ FIGURE 5



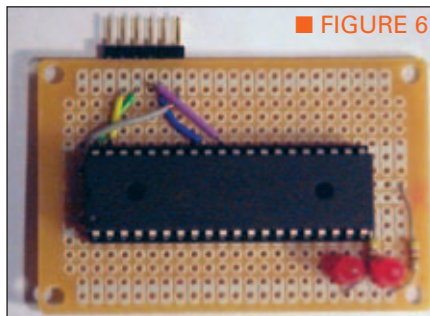
(as seen in Figure 5), the PICkit2 software will generate a new OSCCAL value and put it at the last location of memory just like it wasn't erased.

I had to try it out and it worked even though it didn't get the exact same value every time. But, it was very close. (Not sure how it works, but it's a great option.) Notice that the Data and Clock lines are called ICSPDAT and ICSPCLK on the 12F675 parts. The labeling changes a little from part to part in the data sheets for some reason.

QUICK AND DIRTY BOARD

I recently wanted to try out one of the new 16F887 PICs that I just got from **Mouser.com**. These are the next generation of PICs that take the 16F877A to a new level. Plus, they are cheaper than the 16F877A. Microchip also offers a 16F886 to upgrade the 16F876A that I like to use. I also ordered some of those from **mouser.com**, but haven't received them yet. The latest version of PICBasic Pro (which is 2.47) adds support for

■ FIGURE 6



a nice feature.

ICSP PIN-OUT

As a final note, I thought I would give you the ICSP pins for the various PIC DIP packages.

Table 1 summarizes it for you. This should save you the trouble of looking through all those data sheets.

CONCLUSION

Hopefully, I've explained this well enough that you can plan your next PIC board layout around ICSP. One of the advantages to using the bootloader in my Ultimate OEM module was the ability to use a simple serial cable as the connection device and the ability to run the MCStudio Plus in-circuit debugger that I talked about in a previous article. With the small size of this PICkit2 and also adding to the fact that the PICkit2's cousin — the PICkit2 Debug Express — can do in-circuit debugging through the same six-pin ICSP connector, I'm forced to rethink my development module layout. I have a friend who's been working on his own development board designs based on this new PICkit2 setup. I'll see what he's up to and maybe report on that in another article. The PICkit2 Debug Express only supports a few PICs right now, but I expect that to grow.

Send me your Emails on future topics you'd like to see. I know several people will read this and say "He listened — he actually wrote what I asked!" (If nobody reads my articles, N&V will tell me to hit the road so why would I do anything else!) I want to keep it interesting and progressive as your knowledge expands about PICs, so please Email me your feedback. I read it all. Send it to the email address listed below. You can always visit my website, as well, at **www.elproducts.com**. See you next month. **NV**

these parts. My problem is my EZPIC programmer relies on the ic-prog.com software and it hasn't been updated for this part yet. The PICkit2 does support the 16F88x parts, but the board that comes with it doesn't have a 40 pin or 28 pin socket. Therefore, I decided to use this ICSP method to create a quick and dirty 40 pin programming socket for the PICkit2. Figure 6 shows the result.

It's not pretty, but it worked. I even added a couple LEDs so I could test it with a few Flash LED programs. The 16F88x parts have internal oscillators so I didn't need to add an external resonator. This was an upgrade from the 877A. I also could tie the MCLR pin high internally with a configuration setting so I didn't need the external resistor. The PICkit2 can power the circuit through the six-pin ICSP connector Vdd and Vss connections, but it is limited. The USB port can only supply 100 mA and the PICkit2 draws some current. If you need less than 50 mA, you should be fine powering from the PICkit2, but don't quote me on that — I'm just speculating.

Since this was so simple, I let the PICkit2 power this guy while it flashed the LEDs. The project worked great so now I'm thinking about laying out several different plug-

in boards for my home lab. Being able to simply plug in the PICkit2 to both program and power the board is

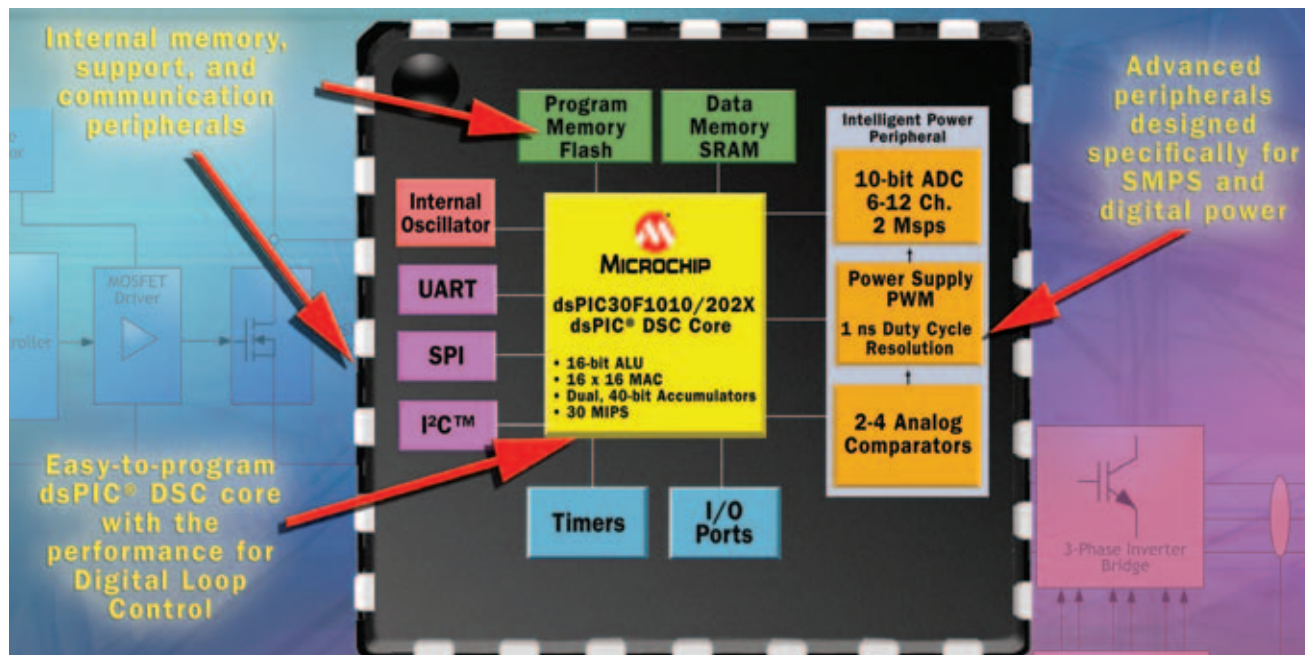
ICSP Connection	40 pin DIP	28 pin DIP	20 pin DIP	18 pin DIP	14 pin DIP	8 pin DIP
Vpp\MCLR	1	1	4	4	4	4
Vdd	11 & 32	20	1	14	1	1
Vss	12 & 31	8 & 19	20	5	14	8
Data	40	28	19	13	13	7
Clock	39	27	18	12	12	6

■ TABLE 1

ABOUT THE AUTHOR

■ Chuck Hellebuyck can be reached at **chuck@elproducts.com**

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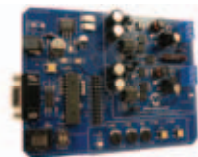
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dsPIC30F2020	28	12	8	8	4
dsPIC30F2023	44	12	12	8	4

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■ BY L. PAUL VERHAGE

USING GOOGLE EARTH TO CHART A NEAR SPACE FLIGHT PATH (Or Your Other Travels)

AFTER MY NEAR SPACE MISSION WITH THE Adler Planetarium in Chicago this summer, Mark Hammergren of the Adler introduced me to Google Earth. I had heard of Google Earth before, but I hadn't paid much attention to it. But once I saw what Mark had done, I realized I should have researched Google Earth long ago. I've developed a Google Earth standard for my near space data that I'd like to share with you this month. And after reading this month's column, I think you'll be as impressed with Google Earth as I am.

Google Earth is an online database and application, so you'll need access to the Internet to run it (see Figure 1). The program uses a small data file containing the near spacecraft's positions as input and

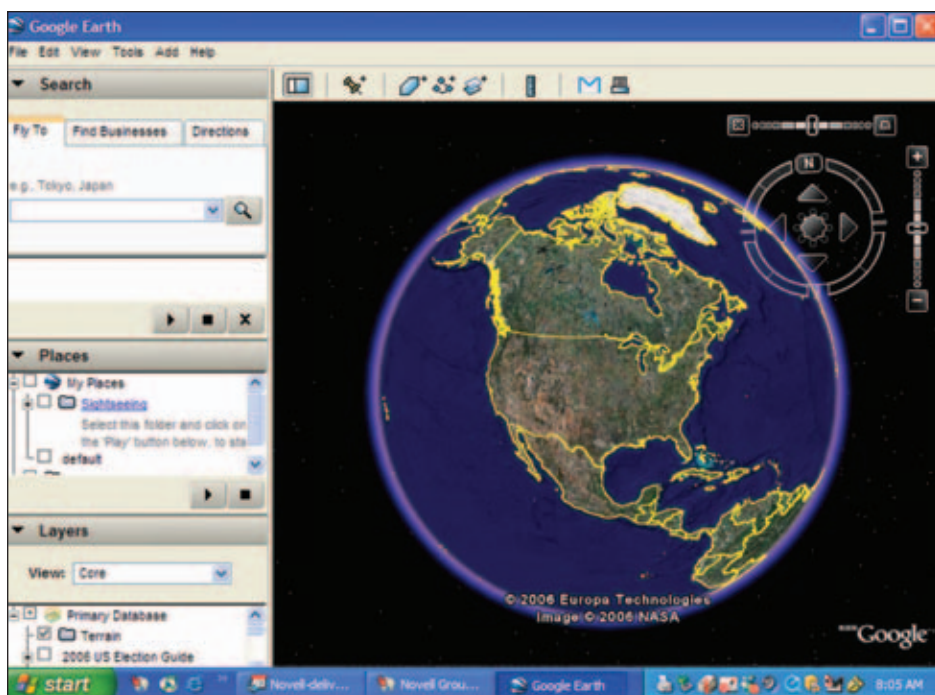
formatting instructions for its output. The instructions are written in a form of HTML called KML. A Google Earth KML file is small and simple enough that it can be written with Notepad.

First, you need to install the

Google Earth application. The minimum PC configuration that Google recommends is a Pentium 3, 500 MHz system running Windows 2000 (choke!) or XP with 128 MB of RAM, 400 MB of free space on the hard drive, and a network connection of at least 128 Kbits/second. On the Mac side of the house, the minimum system requirement is a G3 500 MHz system running Mac OS X 10.3.9 with 256 MB of RAM.

Got that? Then start your browser and go to the website, <http://earth.google.com/>. There you'll find a link called Get Google Earth (Free Version). Click on this link and install Google Earth on your PC. There's a short KML tutorial at http://earth.google.com/kml/kml_tut.html and more complete tutorials at http://earth.google.com/kml/kml_21tutorial.html and http://earth.google.com/kml/kml_tags_21.html. What I'm going to show you in this month's column is enough for you to start writing your own KML files, so you don't need to read the documenta-

tation right way.



■ FIGURE 1

I suppose the best way to understand KML is to look at a Google Earth KML file. Table 1 shows a file I've edited for one of my near space flights. Note that I've shortened the number of positions in the sample file considerably. The usual number of positions listed in one of my typical KML files is over 100.

Like HTML, KML commands — or element names — are written in brackets, < and >. Parameters for a particular command are written after the <COMMAND> begins and before the </COMMAND> ends.

The first element names I edit are <DESCRIPTION> and <NAME>. When the image of a flight path is clicked on a Google Earth map, the text entered in these two elements is displayed. I like to write the mission name and date in these elements.

Next, I edit the element names under <LOOKAT>. These seven elements indicate where in space to place and point your eyeball. The <LATITUDE>, <LONGITUDE>, and <ALTITUDE> element names indicate the point above the earth to stare at. The <RANGE> and <TILT> element names indicate the distance and angle to look from. The <HEADING> element name is the compass direction your eyeball points. Since the near spacecraft's GPS altitude is with respect to mean sea level, the <ALTITUDEMODE> is set to ABSOLUTE. Figure 2 shows my diagram of what the <LOOKAT> element names mean.

The <LOOKAT> point in the sample KML file is a location at the center of the near spacecraft's flight ground track and half way up to its maximum altitude. Its

tilt is 90 degrees (horizontal), with a heading of 0 degrees (true north). The range is equal to the flight path's maximum altitude (I sometimes have to edit this after looking at the results). A word of caution here. The altitude and range elements are in units of meters. Until I realized that, my flight paths looked awfully tall and skinny (just like me when I was younger).

The only name elements modified under <STYLE> are <LINESTYLE COLOR> and <WIDTH>. The <LINESTYLE COLOR> element is an eight byte field. The first two bytes indicate the transparency of the line and the remaining six bytes indicate its color. A transparency of hex 00 creates an invisible line and a hex value of FF creates a fully opaque one. The next three pairs of bytes are for the colors blue, green, and

red (in that order). In the sample KML file, the <LINESTYLE COLOR> is set to ff000000. That draws the flight path as a fully opaque black line. The <WIDTH> is set to two just because that seems to work well.

The last name element modified is <EXTRUDE>. Extruding a flight path drops a curtain from the flight path to the ground. I find the curtain confusing, so I don't have it drawn. To NOT extrude a flight path, type,

TABLE 1

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.0">
  <Placemark>
    <description>Flight of NearSys 05B</description>
    <name>29 May 2005</name>
    <LookAt>
      <longitude>-119.78</longitude>
      <latitude>47.78</latitude>
      <altitudeMode>absolute</altitudeMode>
      <altitude>13400</altitude>
      <range>26800</range>
      <tilt>90.0000</tilt>
      <heading>0.000000</heading>
    </LookAt>
    <visibility>1</visibility>
    <open>0</open>
    <Style>
      <LineStyle>
        <color>ff000000</color>
      </LineStyle>
      <width>3</width>
      <PolyStyle>
        <fill>0</fill>
        <color>0000ff00</color>
      </PolyStyle>
    </Style>
    <LineString>
      <extrude>0</extrude>
      <tessellate>0</tessellate>
      <altitudeMode>absolute</altitudeMode>
      <coordinates>
        -119.7523333,47.9435,1176.219512
        -119.7525,47.94333333,1230.182927
        -119.7526667,47.943,1285.060976
        -119.753,47.9425,1338.109756
        -119.7533333,47.942,1392.987805
        -119.7536667,47.9415,1450
        -119.754,47.94066667,1504.268293
        -119.7541667,47.94,1560.060976
        -119.7545,47.93933333,1619.207317
        .
        .
        .
        .
      </coordinates>
    </LineString>
  </Placemark>
</kml>
```

FIGURE 2

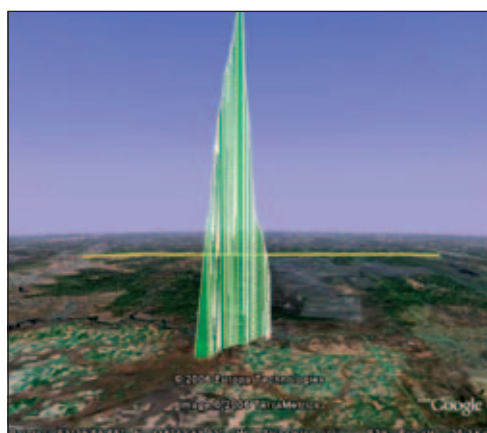
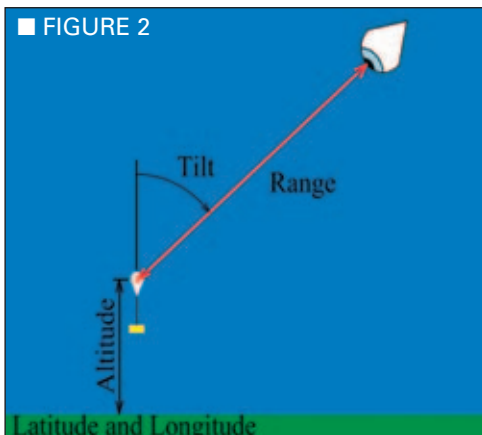


FIGURE 3. The extruded flight path.

<EXTRUDE>0</EXTRUDE>. If the zero between the <EXTRUDE> elements is changed to a one, the flight path looks like that in Figure 3.

Now it's time to add the coordinates of the balloon's path. There's only one coordinate per line of text and each coordinate is a point in three-dimensional space with the following format: longitude, latitude, altitude. Since the United States is west longitude, longitudes here are written as negative numbers. If you forget to add a negative in front of the longitudes, your flight path will be drawn above western China. The longitude and latitude are written in decimal degrees, so you need to convert minutes of latitude and longitude in decimal degrees. Don't forget, the altitude is in units of meters.

I get my balloon positions over APRS, a form of digital communications. The position reports are generated by a Tiny Trak 3* and after I clean up the text file, it has a format that looks like this:

124845,38,23.55,098,09.34,044,022,018837

The fields are time (in UTC), latitude, longitude, heading, speed, and altitude. Only the fields that are bolded in my example are required to create the rest of the KML file.

It's easiest to load the entire APRS report into Excel as a comma delimited text file and then let the spreadsheet do the formatting work for you. Because I need the time of day in my data analysis, before opening the file in Excel, I first break the time field (which is the first field in my APRS report) into three fields (hours, minutes, and seconds). In Excel, I insert a fourth column called Mission Elapsed Time (that's calculated from the previous three columns). That's why my equations for longitude begin in column G rather than column D.

Here are the equations I use to convert the longitude into negative decimal degrees, the latitude into decimal degrees, and the altitude into meters:

Longitude Equation
= -G1-(H1/60)

Latitude Equation
= +E1+(F1/60)



Altitude Equation
= +K1/3.28

After writing the three equations into three neighboring cells in the first row, copy and paste them all the way down the columns. You need three more pieces of information before calling it quits with Excel: the midpoints of the ground path (latitude and longitude) and altitude. Those three values become the <LOOKAT> coordinates. I use Excel's AVERAGE command to calculate the midpoint of the latitude and longitude. However, since the ascent is slower than the descent, this calculated midpoint is weighted a bit to the ascent portion of the flight. If you really want to find the midpoint of the ground track, then you need to find the minimum and maximum values of latitude and longitude, add the values together, and then divide by two. The equation to find the midpoint in Excel is (this is assuming the last row of data is number 300):

= AVERAGE(G3..G300)

If you really want to be correct, then the midpoint equation becomes:

=(MIN(G3..G456)+MAX(G3..G300))/2

For simplicity, I just use the first equation.

Since it's easy to visually find the highest value in the altitude column, I use the following Excel equation to calculate the midpoint of the maximum altitude (assuming the maximum value is located in cell I203):

= +I203/2

Begin Notepad and open your generic KML file (a sample is available on the *Nuts & Volts* website; www.nutsvolts.com). Replace the <LOOKAT> elements of <LATITUDE>, <LONGITUDE>, <ALTITUDE>, and <RANGE>. Now highlight all the cells in the three new columns (be careful, the first column won't be highlighted just after a paste) and cut them out by clicking EDIT > CUT. Start a new workbook by clicking FILE > NEW. Select Blank Workbook because Excel doesn't assume it's a new workbook. PASTE

the three columns in the new workbook and save the workbook in a comma delimited format, by clicking, FILE > SAVE AS. Under the Save As Type option, select, CSV (Comma Delimited). Don't forget what directory the file is saved in.

You should save your Excel file in case you discover an error in the positions reported in your KML file. It's easier to doctor the old Excel file than to create a new one.

Under Windows Explorer, right click on the comma delimited file

once and select OPEN WITH > Notepad. Don't let Excel open the file or else you'll find it back in a spreadsheet. Highlight the entire text file and click EDIT > COPY. Close down the file and open the sample KML file (if it's closed). Highlight just the old coordinate data between <COORDINATE> and </COORDINATE> and click EDIT > PASTE to replace the old coordinate data with your new coordinates. Save the file as a KML file by clicking FILE > SAVE AS, then selecting ALL FILES in the SAVE AS TYPE window. Be sure to end the name of the file with .KML. That's it, you're done! You have a complete KML file ready for Google Earth.

Start Google Earth and click on FILE > OPEN. Select your new KML file and watch the magic. You can change the view of the flight path by clicking on the ground and dragging the mouse. You can also change the view of the flight path by adjusting the controls in the upper right-hand corner of the screen. The compass rotates to a new heading, the vertical slider bar on the right side changes the range; and the horizontal slider bar on top changes the tilt. You'll get a three-dimensional feel for the flight path as you move around it with these controls.

When I'm happy with the display of the flight path, I save the image by clicking on FILE > SAVE > SAVE IMAGE. Figure 4 shows an example of what I end up with.

Something I discovered after loading up a new flight path is that the old ones are still stored in memory. I got to see the flight paths of two earlier missions in Nebraska from the perspective of a later mission in Kansas.

The two distant flight paths may be difficult to see in Figure 5, but they're clearly seen in Google Earth. Besides, I can drag the earth around with my mouse and zoom up to these flight paths. Now, if I could only drive that fast ...

No doubt I've just begun to scrape the surface of Google Earth. I want to experiment next with putting myself on top of the flight path and see what the near spacecraft is seeing. If you're ready to give Google Earth a try with near space, install the program and give my mission NearSys 05B.KML file on the *Nuts & Volts* website a spin. I can just image a day in the not-too-distant future when power lines and houses will be accurately mapped in Google Earth. Then, I can select a location in my front yard and see what it looks like outside my house without leaving my PC. Virtual reality anyone?

Onwards and Upwards,
Your Near Space Guide **NV**

* A Tiny Trak 3 is essentially a one-way radio modem. You can purchase it online at www.byonics.com.

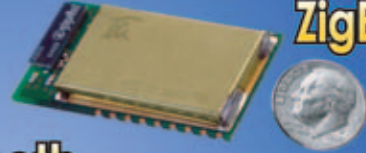
FOR YOUR INFO

I've created a website of my past near space missions. There are images and data for most of my 62 missions. While you're there, you can download KML files for many of my flights and run them through Google Earth for yourself.

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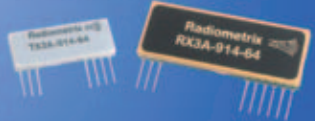
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Address: _____

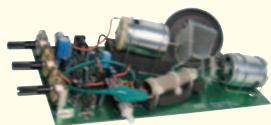
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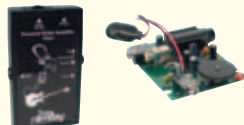


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PGA1 Guitar Amp Kit 64.95

ECG Heart Monitor

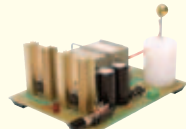


Check your own heart!

Provides a visible and audible display of your heart rhythm! Variable gain, bright "beat" LED, and monitor output for display on your scope. Just like the lab! Reusable sensors are included. Runs on a safe 9VDC battery.

ECG1C ECG/EKG Kit 44.95

Plasma Generator

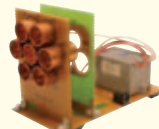


Generate 2" sparks!

Produces a stunning and shocking 25kV at 20kHz from a solid state circuit! Build your own plasma bulbs, light fluorescent tubes without wires and more! A great learning kit. Runs on 16VAC, order our PS21 power supply.

PG13 Plasma Gen Kit 64.95

HV Ion Generator



Make a blast of fresh air!

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IG7 Ion Gen Kit 64.95

20W SubMini Audio Amp



20 watts and no heat!

Delivers a super clean 20W output from one SMT package! Ultra efficient class D design produces no heat. PCB can be snapped into a small circle for special applications. Runs on 18VDC for rated output, use our SPS18 PS.

UAM2 20W SMT Amp Kit 34.95

Digital Voice Storage



Multiple message storage!

The Bullshooter-II provides up to 8 minutes of digital voice storage that can be broken down into 8 separate stored messages! Great for announcements, etc. Built-in mic plus external input. Runs on 12VDC or our AC125 PS.

BS2C Bullshooter-II Kit 69.95

Speed Radar Gun



Now YOU can be the cop!

Our famous Speedy radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. 1/8th mile range is typical. You supply two coffee cans! Runs on 12VDC or our AC125 power supply.

SG7 Speedy Radar Kit 59.95

Doppler Direction Finder

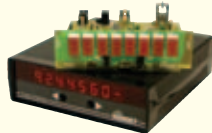


Find that transmitter quick!

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1 Dir. Finder Kit 169.95

Touch-Tone Reader



Read the number dialed!

The Tone Grabber captures dialed phone numbers, repeater codes, control codes, or anything that uses touch-tone signaling. Flash micro stores 640 digits! Phone line and audio inputs. Runs on 12VDC or our AC125 PS.

TG2C Tone Grabber Kit 69.95

Signal Magnet Antenna

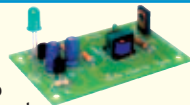


Pulls in distant stations!

Super Hi-Q ferrite rod antenna with Faraday shield eliminates noise from power lines, dimmers, static and more! Great results from 500kHz to 15MHz. Super for AM broadcast band! Includes power supply.

SM100 Sig Magnet Kit 89.95

Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk. "Hey, I told you not to touch!" Runs on 3-6 VDC

TS4 Tickle Stick Kit \$12.95

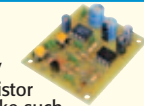
Super Snoop Amplifier



Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9 Super Snoop Amp Kit \$9.95

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Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

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BL1 LED Blinky Kit \$7.95

Cricket Sensor



Senses temperature and changes the chirp accordingly. Can actually determine temp by chirps! Runs on 9VDC battery. Speaker included.

ECS1 Cricket Sensor Kit \$24.95

Electronic Siren



Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3 Electronic Siren Kit \$7.95

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5 Universal Timer Kit \$9.95

Voice Switch



Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1 Voice Switch Kit \$9.95

Tone Encoder/Decoder



Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1 Encoder/Decoder Kit \$9.95

RF Preamplifier



Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit \$19.95

Touch Switch



Touch on, touch off, or momentary touch hold, your choice! Uses CMOS technology. Runs on 6-12 VDC and drives any load up to 100 mA.

TS1 Touch Switch Kit \$9.95

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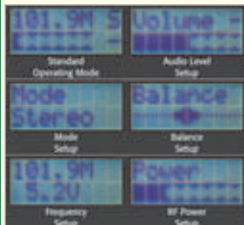
Where YOU are the DJ!

Digital FM Stereo Transmitters

- ✓ Rock stable PLL synthesized
- ✓ Front panel digital control and display of all parameters!
- ✓ Professional metal case
- ✓ Super audio quality!
- ✓ 25mW and 1W models!



For nearly a decade we've been the leader in hobbyist FM radio transmitters. The FM30 series of transmitters is the latest and greatest! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!



The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done through the front panel digital control and LCD display! All settings are stored in non-volatile memory for future use.

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. (Note: The end user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US).

FM30B Digital FM Stereo Transmitter Kit, 0-25mW, Black \$199.95
FM35BWT Digital FM Stereo Transmitter, Assembled, 1W, Black \$299.95

Professional Synthesized Stereo FM Transmitter

- ✓ Fully synthesized 88-108 MHz for no frequency drift
- ✓ Line level inputs and output
- ✓ All new design using SMT technology



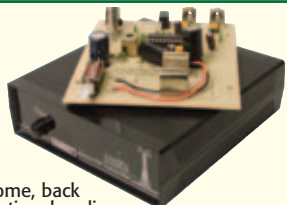
Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer!

A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's "digital" receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, easy assembly instructions, and the SMT parts are factory preassembled - you'll be on the air quick!

FM25B Professional Synthesized FM Stereo Transmitter Kit \$139.95

Tunable FM Stereo Transmitter

- ✓ Tunable throughout the FM band, 88-108 MHz
- ✓ Settable pre-emphasis 50 or 75 µsec for worldwide operation
- ✓ Line level inputs with RCA connectors



The FM10C has plenty of power to cover your home, back yard, or city block. You'll be amazed at the exceptional audio quality of the FM10C. Tunes through the entire 88-108MHz band. Re-broadcast your favorite music commercial free and with the dynamic range the musician intended, without all that nasty compression the big boys use to make their station sound louder than the competition. Compression produces a noticeably muddier and less dynamic sound. Runs on an internal 9VDC battery, external 5-15VDC, or our AC125 AC power supply.

FM10C Tunable FM Stereo Transmitter Kit \$44.95
AC125 110VAC Power Supply \$9.95



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Passive Aircraft Airband Monitor

- ✓ Monitors the entire aircraft band without tuning!
- ✓ Passive design, can be used on aircraft, no local oscillator, generates and creates no interference!
- ✓ Great for air shows
- ✓ Patented circuit and design!

For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the one you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

1. At an air show! Just imagine listening to all the traffic as it happens
2. Onboard aircraft to listen to that aircraft and associated control towers
3. Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)
4. Commercial pilots to monitor ATIS and other field traffic as needed at their convenience
5. General aircraft monitoring enthusiasts

Receiver sensitivity is less than 2uV for detectable audio. Headset cord is coupled as the antenna giving you great reception. Also includes a set of stereo ear buds. Runs on a standard 9V battery. For the hobbyist this unique receiver is available in a do-it-yourself through-hole hobby kit. It is also available as a factory assembled & tested SMT version to get you listening quick! Check the review in the November 2006 Monitor Times magazine!

ABM1 Passive Air Band Monitor Kit \$89.95
ABM1WT Passive Air Band Monitor, Factory Assembled & Tested \$159.95

3-In-1 Multifunction Soldering Lab

- ✓ ROHS soldering station!
- ✓ Digital multimeter!
- ✓ Regulated lab power supply!
- ✓ Everything all in one unit!



Take a close look! On your left is a multi-function 3 1/2 digit digital multimeter. Its large backlit LCD display can be seen from anywhere on your bench while you're working. The DMM also features built-in transistor, diode, and continuity testing, data hold, and audible alarm. Next up, the regulated lab DC power supply. Switch selectable ranges of 3V, 4.5V, 6V, 7.5V, 9V, and 12V provide a continuous duty current of 1.5 amps with a 2 amp peak! Features both overload protection and overload indication.

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LAB1U 3-in-1 Multifunction Soldering Lab \$119.95

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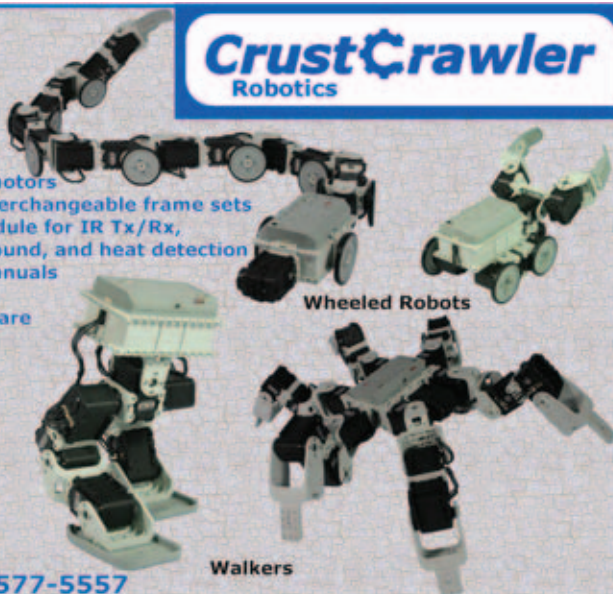
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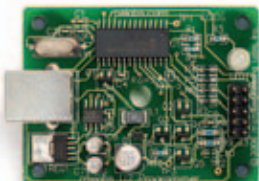
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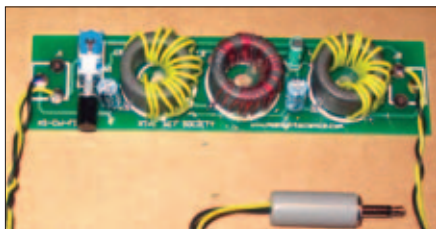
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XS-PCWFK PASSIVE CW FILTER



The Xtal Set Society announces the availability of their latest radio kit — a passive CW filter, the XS-PCWFK. This filter features a ~400 Hertz bandwidth with 750 center frequency and requires no battery or supply. The kit includes a bonus of sorts in that it may be configured as an SSB rather than CW filter with a change in components. It goes between your receiver or rig — audio output — and eight-ohm speaker or phones, and accommodates old-style hi-z headphones too, such as Baldwin's.

The kit is assembled on a 1.25 by 5.0-inch printed circuit board. Jacks, plugs, and cables are not included. An assembly manual is provided, and solder assembly is required. For most hobbyists, kit assembly is about one-half hour. A completed assembly is shown in the photo above.

The XS-PCWFK Passive CW Filter Kit is \$19.95 plus \$4.95 shipping/handling.

Orders may be placed via the website catalog at the address listed below.

For more information, contact:
The Xtal Set Society

PO Box 3636

Lawrence, KS 66046

Tel: **405-517-7347**

Email: xtalset@sunflower.com

Web: www.midnightscience.com

NEW HAND-HELD DSO/DMMs HAVE 125 kB RECORD LENGTHS

A series of high performance, hand-held DSO/DMMs have been introduced by Protek Test and Measurement



featuring record lengths of 125 kB and real-time sampling rates to 200 Ms/S.

The new entries consist of the 60 MHz model (860), the 40 MHz model (840), and a 20 MHz model (820). The 40 MHz model also features a repetitive sampling rate of 2.5 Gs/S, and the 60 MHz model features 5Gs/S. These dual channel DSOs have a deep 125 kB record length (each channel) together with high sampling rates, providing users with an excellent tool for capturing high speed glitches and analyzing digital and analog signals in far greater detail than competitive models.

Along with a built-in FFT (Fast Fourier Transforms) for signal analysis, these DSOs provide math functions ChA + ChB; ChA - ChB; ChB - ChA; plus a zoom function for expanding a segment of waveforms of interest; 20 automatic waveform measurements; and USB interface for high speed communication with a PC. An optional USB host port Flash Memory significantly increases waveform storage capabilities.

The DSOs also function as auto-ranging 6,000 count True RMS DMMs with 600 volt Category III ratings and 600A current capability.

The Model 820 is priced at \$1,072 (MSRP); the Model 840 is priced at \$1,336 (MSRP); and the

Model 860 is priced at \$1,559 (MSRP). Standard accessories include: AC/DC adapter, 7.2V NiMH rechargeable battery pack, two x1x10 oscilloscope probes, USB cable with software, meter test leads, user manual, and holster. USB Flash Memory modules are optional, along with clamp current probes and carrying pouch.

For more information, contact:

Protek Test and Measurement

Web: www.protektest.com

techFX 1.0b CONTROLLER BOARD



The Silicon Horizon, Inc., has announced a new controller — the techFX. It's performance features include:

48 MHz Microchip 18f4550 MCU at 12 MIPS; full speed USB 2.0 communications; bootloader through USB allows easy firmware upgrading; 32K memory on MCU; 256K memory on (2) 1 MHz I²C EEPROMS; and switching power supply for low heat, high current operation.

The switching power supply includes: dual voltage operation for running 12 or 24 volt motors, solenoids, valves, etc.; five volt line on switching regulator up to one amp; external voltage line current up to one amp (wall adapter voltage); low heat dissipation (<1 watt) from switching supply; 2.5 mm DC power jack (CP) for larger wall adapters; ability to run 12 and 24 volt solenoids, motors, valves; and a wide DC input 9-30 VDC.

Another performance feature of

the techFX is the main power switch and external voltage power switch which allow high current outputs to be switched off. The board is 4" x 5" in dimension.

There are 31 total I/O consisting of: eight high current outputs through a Darlington array; 17 configurable I/O featuring up to eight A-to-D lines at 10 bit resolution; up to two PWM lines configurable from 3 kHz-4 MHz; all I/Os are configurable as input or output; and six I²C bus headers configurable at 100,400 kHz and 1 MHz speeds.

Additional features include socketed components for easy replacement, switching power supply can be replaced and upgraded to a higher power unit, memory can be upgraded, power LEDs show when main power and external power switches are on, bootload jumper, and reset switch. Circuit board standoffs are included.

All high current outputs are on screw type terminal blocks. Screw terminals feature +5V, ground, and external voltage lines.

All I/O are on three pin headers (.100 in) with +5 volts and ground pins.

techFX tools (included software)

techFX tools is now shipping free with all controller boards. The software contains a board and sequence editor and programmer along with a USB bootloader to program new firmware into the techFX.

With techFX tools, you can create a board configuration and control sequence in minutes and apply the controller to different projects fast and easily without writing any code.

Features include integrated USB bootloader for programming firmware, create, print, save, load controller configurations easily, switch pins between input, output, PWM, A-to-D in seconds and program the configuration with a click of a button, change the number of A-to-D, PWM lines in seconds, and change the I²C bus speed for really long cable runs (100 kHz, 400 kHz, or 1 MHz).

Use the I/O tester screen to test

your pin configuration with your application device connected (i.e., motor or sensor) and read values and execute functions before putting your application together

Create, print, save, and load control sequences with up to 255 commands and up to 60 minutes in length with a time resolution of a tenth of a second.

Use the following logic devices to control the flow of your control sequence:

- Loop
- Run once
- If input true/false
- If input less than/greater than (for analog input readings)
- Wait on input true/false

A bootloader for programming firmware to the controller is included.

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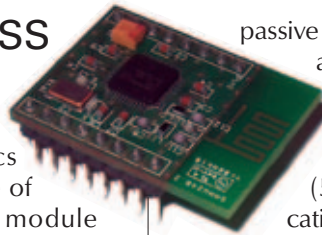
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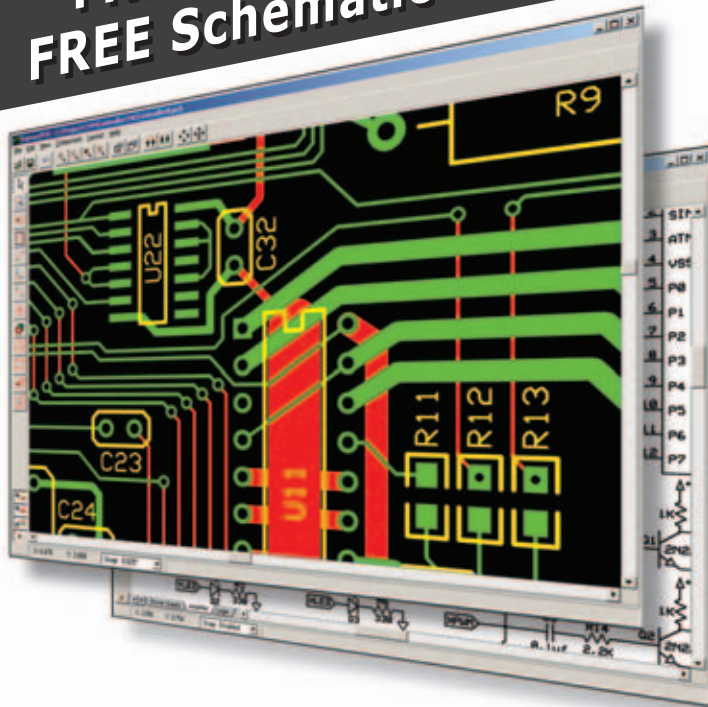
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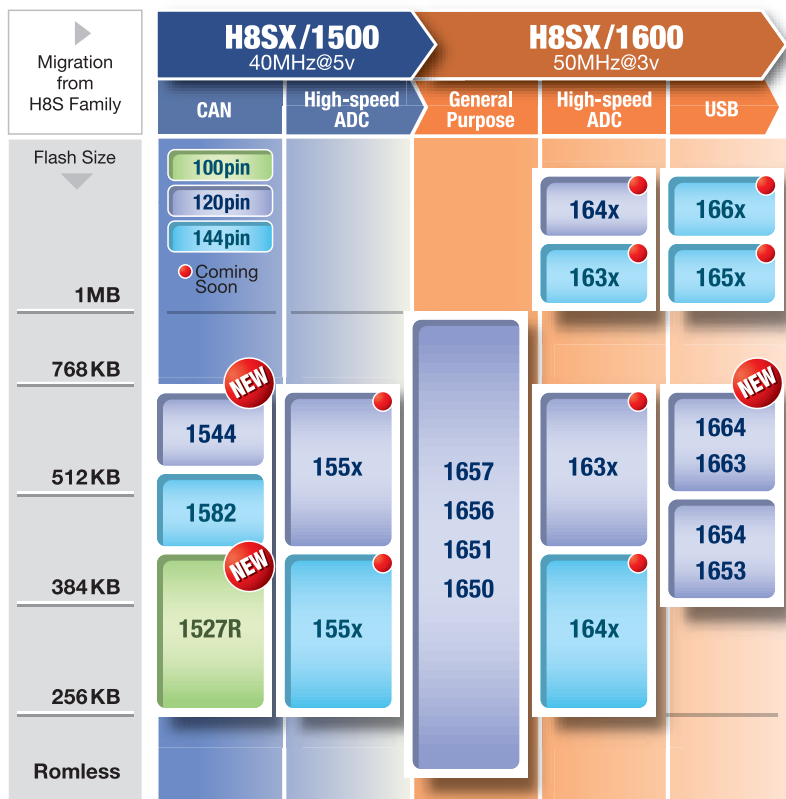
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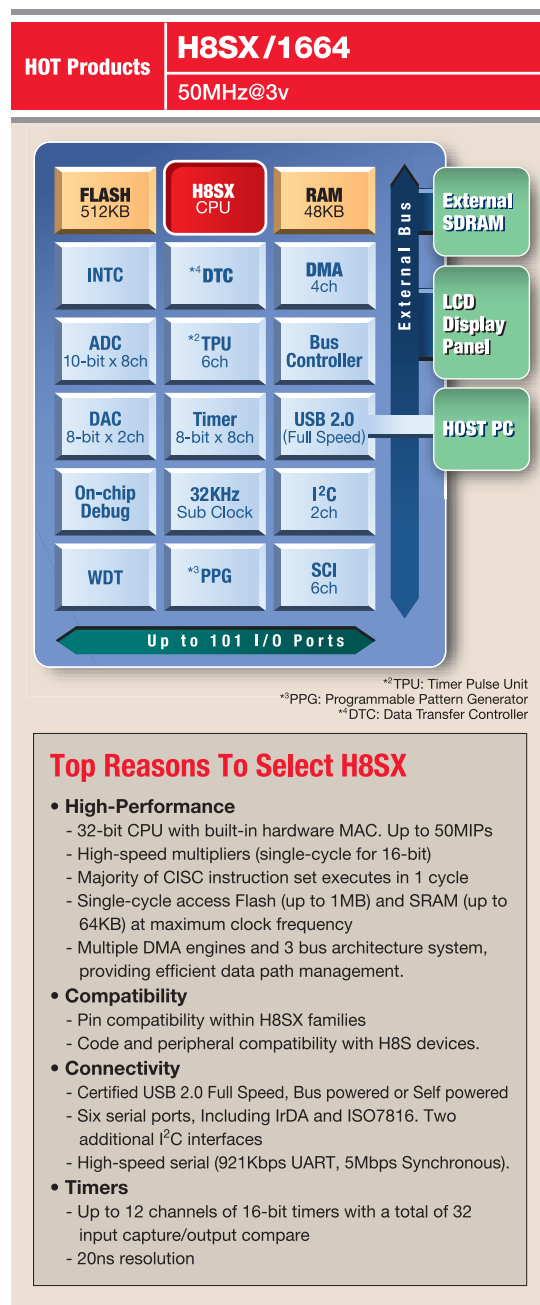
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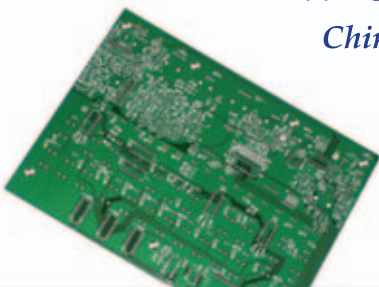
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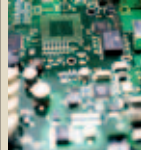
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■ THIS MONTH'S PROJECTS

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■ LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

- Beginner Level
- Intermediate Level
- Advanced Level
- Professional Level

Last month, I introduced you to various anemometers that could be used in building your own weather station. In this article, I want to show you how to use additional sensors,

but first I want to delve a little deeper into the 1-Wire interface.

CONTROL YOUR WORLD

Home Automation: Environmental Sensors

1-Wire Chips

A few years ago, Dallas Semiconductor (now owned by Maxim) invented a protocol that would allow them to connect multiple chips to a host using a minimal pin count. That is how 1-Wire was born. The chips shown in Figure 1 are just a small sampling of the 1-Wire chips available. Notice the different form factors. The small speck just below the two surface-mount chips is a DS2401 chip.

One of the chips we will be using throughout this series is the DS18S20 digital thermometer. This chip comes in both a surface-mount and TO-92 format, which makes it perfect for the hobbyist.

1-Wire Protocol

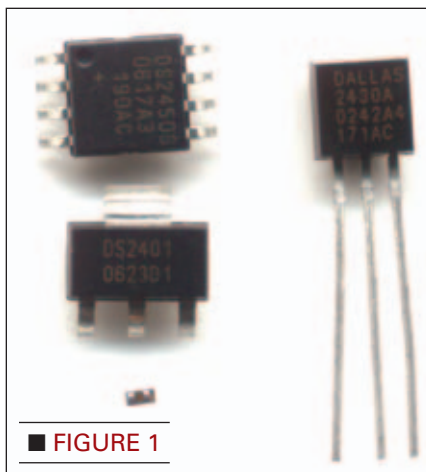
Before I jump into the techno

babble, I want to assure you that whether you use a PC or a microcontroller, low level routines have been provided to handle the 1-Wire protocol. The protocol information presented here is for the sole purpose of satisfying your inner geek.

The protocol is called 1-Wire because it uses a single wire for both transmission and reception of data. In reality, two wires are needed, as a return wire is also required, but the data itself is carried on the data lead. The protocol uses time slots to determine the presence or lack of a single bit in a said time slot. Multiple bit time slots are used to transmit and receive bytes or words. There are no external timing pulses so the protocol is considered asynchronous in nature and has very stringent timing guidelines.

The protocol allows multiple chips or devices to be placed on the same two wires, which is sometimes called a bus. This bus has a single master and one or more slaves. The bus is held high by a pull-up resistor or some other means. This is normally done on the master end of the bus. The master can provide a hard pull-up when needed to provide power to the chips in parasite mode, which we will get into a little later. A slave chip or device can only pull the line low. During a single bit time slot, a slave will let the bus float, thus signaling a 1, or pull it low signaling a 0.

In order to communicate with



■ FIGURE 1

individual devices on the bus, each 1-Wire device has a unique 64-bit registration number that allows that chip to be targeted for communications. The first eight bits in this registration number are the family code. This code is used to identify the device type. The next 48 bits (six bytes) represent the serial number for the slave. The last eight bits are a CRC of the first 56 bits.

The 1-Wire protocol also specifies a search algorithm for identifying all the slaves on a bus. By using the family code we can actually display the serial number and chip type of each chip connected to the bus. I used this feature last month in the test applications and will be using it in this article, as well. I have included a small application called RomSearch Form.exe that will allow you to display all the chips connected to your DS9097U adapter.

1-Wire Network

Once we start adding chips to the bus, it becomes a network. Dallas calls this a MicroLAN. A network requires one master and at least one slave to operate. As previously mentioned, the protocol is written so that you can place as many slaves on the network as you wish, but in practice, once you get more than 20 or so slaves on the network, loading and other issues can start to cause communications issues.

The length and type of cable used for the network will determine how many devices you can actually place on the network. For short distances of under 10 feet, just about any cable will work. Unfortunately, we are building a weather station so long cable lengths are a fact of life. In most cases, you will have a cable longer than 100'. The best cable for running longer lengths is CAT5 or CAT5e. In a pinch, you can use CAT3 but I don't recommend it in lengths longer than 200'.

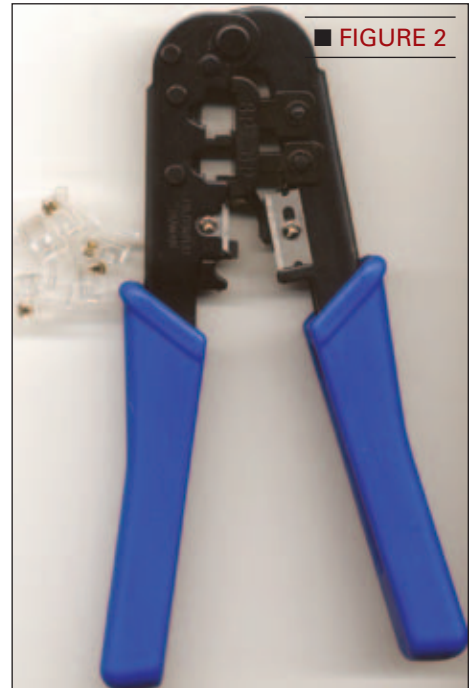
In many of my current configurations, I run a CAT3 cable 200' to my various weather poles and it works

just fine, but I am pushing it. I have taken special care to make sure the network cable does not cross any power lines or equipment that can cause interference. As you probably know, CAT5 cable is used to connect your PC to the Internet or other computers. CAT3 cable is simply twisted pair telephone cable. You can purchase both of these at your local home center or RadioShack.

CAT5 cable has eight wires. In our weather station, we will use only two of these wires. In most cases, it will be the blue and blue/white wire. For CAT3, there are four or six wires and we will use the red and green wires. The reason we are using particular colors is that the wires in the cable are twisted in pairs. This twist helps alleviate unwanted interference in the cable. Many companies (like Hobby Board, for example) use RJ connectors on their 1-Wire boards. The colors we have chosen map out to the center pins on those connectors (most of the time).

When building 1-Wire network cables, it is absolutely essential that you keep the cable lengths at a minimum. Do yourself a favor and purchase a modular plug crimper. You can pick up a lightweight crimper for under \$10 from RadioShack. The heavy duty metal crimper shown in Figure 2 was purchased from my local home center for \$20. It will crimp RJ11/12 and RJ45 modular plugs. It also cuts and strips both round and flat data cables.

On my weather pole, I mounted an outdoor receptacle box. It can be purchased from most home centers along with a sealed waterproof cover. I oriented the access hole on the bottom of the box and ran all my wires that way. This makes for a nice water-resistant box, but air can still get inside for the humidity sensor. Using a modular splice, I connected my main cable to a five-way junction box like the one shown in Figure 3. This allows me to create small jumpers that run to each sensor.

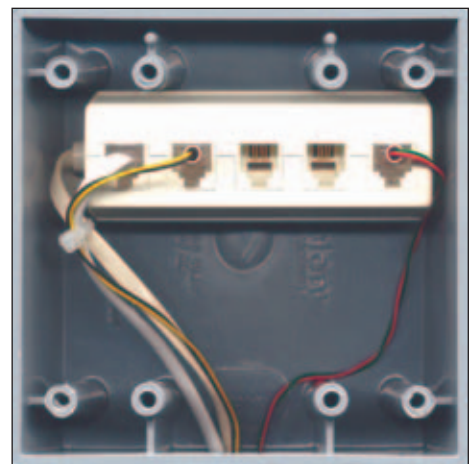


■ FIGURE 2

Troubleshooting 1-Wire Network Problems

Because all the 1-Wire devices are connected in parallel, the only way to troubleshoot a faulty network is to systematically remove devices to determine where the problem is located. The five-way junction box makes it very easy. I use the small test plug shown in Figure 4 and Schematic 1. Plug the test plug into the network and load the RomSearchForm program. The test

■ FIGURE 3





■ FIGURE 4

plug test results are as follows:

- If the network cable is wired backwards (red and green wires reversed), the program will report a network short.
- If the LED blinks but the search reports no devices, the voltages may be too low at the test point.
- If the LED does not blink and no devices are found, you probably have a broken or miss-wired connection.
- If the LED blinks and the DS2401 is identified, the current network segment is wired correctly and working.

■ FIGURE 5



■ FIGURE 6



Parasite Mode

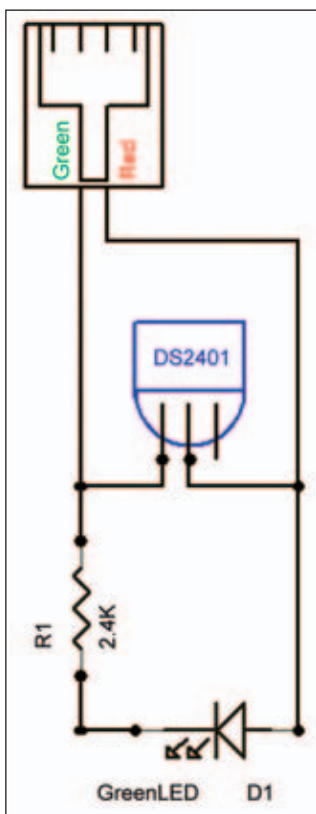
1-Wire chips have the option of running in what is called parasite mode.

When operated this way, they get their power from the 1-Wire bus. There are both advantages and disadvantages of running the slaves in parasite mode.

Disadvantages

- When doing A-to-D or temperature conversions, the master must place a hard pull-up on the data line in order to power the slave during this conversion. This tends to add more delays to the interface process. Also during this process, the master is unable to talk to other slaves.
- Some slaves will lose data when power is removed. This means the chip must be periodically reconfigured. This introduces even more delays and even worse, can cause bad readings until the proper configuration is restored.

■ SCHEMATIC 1



- Some slaves will lose counter data so battery backup at the chip's location may be needed.

- There are times when the sensors that are connected to the 1-Wire chips must be powered.

Advantages

- Since we are only supplying two leads, cable configurations are much simpler.
- If you connect a device

incorrectly, there is little chance of damage.

- Only a single pair in the cable can be used. This allows us to use longer cable runs. If we have to add power to the cable via a second pair, this adds unwanted characteristics to the cable and can affect communications.

- We can reset a chip's counter or configuration by simply pulling the data line low for a period of time. This is important for remote configurations like a weather station. I have had slave devices simply lock up and the only way I could regain access was to remove the power. Not a problem in parasite mode.

Most of our outdoor 1-Wire devices will be powered via parasite mode. If you decide to power the devices and chips normally, only minor changes need to be made. You should run the power using a different cable, however. This is especially true of longer cable lengths.

iButtons

Dallas has placed several of their chips in small stainless steel cans. These devices resemble a small battery (as shown in Figure 5) and are parasitically powered. This makes them very resistant to harsh environments. While we won't be using any of these devices in our weather station, you should take a look at the iButton website at www.maxim-ic.com/products/ibutton/.

Connecting Your PC to a 1-Wire Network

There are a couple of ways to get your PC connected to a 1-Wire network. Dallas makes two adapters. The DS9097U shown in Figure 6 is a RS-232 to 1-Wire adapter. The DS9490R shown in Figure 7 is a USB to 1-Wire Adapter. There are other adapters but they are mostly variants of the DS9097U.

Dallas has made several device drivers available on their website, but I

am sorry to say I found them problematic to install. There were just too many moving parts associated with the drivers.

In order to add 1-Wire support to the Zeus language, I wrote my own low level 1-Wire interface routines to access the DS9097U directly. This means you don't need to install any of the drivers. I have also added several high-level 1-Wire chip libraries, as well.

1-Wire Example

Let's take a real-world example and see what it takes to connect an analog device to a 1-Wire network. Fascinating Electronics sells a wind vane kit that uses a special dual potentiometer as a sensor. The kit shown in Figure 8 is one of the nicest wind vanes I have had the opportunity to work with. With a price tag of only \$49, you can't go wrong.

The only thing you will need is hookup wire. It comes with complete instructions and will take you one to two hours to build. I suggest you do a temporary mount so that you can test your interface before running out and placing the vane on top of a 30' pole. I used about four feet of six conductor telephone wire and attached it to the potentiometer, as shown in the included instructions. I then mounted the vane using PVC fittings so that I could freely rotate the vane during tests, as shown in Figure 9.

In this first example, we will be connecting the wind vane to a DS2450 1-Wire IC chip as shown in Schematic 1. In order to parasitically power the analog circuit, I have added a diode (D1) and a capacitor (C1). These allow us to keep power applied to the wind vane potentiometer in parasite mode while we take our readings. I also added two 1 meg resistors across the wipers and GND. This keeps the voltage level from floating when the wiper is in its dead zone.

Notice that we are only using two of the four A-to-D ports. This leaves us two that we can use later on other sensors. We could easily add a CdS cell to use as a light sensor or a cou-

ple of probes to measure moisture.

One of the reasons I have shied away from using Dallas 1-Wire chips is that many are only available in surface-mount form factors. The DS2450 is no exception and is only available in SOIC form. This is no longer an issue since a company called Schmart Board has solved our surface-mount blues. Their model 202-0004-01 is perfect to use with the Dallas 1-Wire SOIC chips. The chip just sits in a small groove and, using your soldering iron, you simply place the tip in the groove furthest from the chip and move the tip towards the chip. This moves the solder that's already in the groove to the point where the chip is in contact with the groove, as shown in Figure 10. This works pretty well, but make sure you use your multimeter to confirm you have a good solder joint. What I did was to place a very small dab of soldering paste on the tip of the SOIC pin that was being soldered. A small needle works perfect for this.

Figure 11 shows how I wired the circuit in Schematic 2. Note that the blue, orange, yellow, and white wires attach to a series of holes that could be used to connect your own cable or header. Notice that there is plenty of



■ FIGURE 7



■ FIGURE 8

space left on the board to connect one or two more chips. Once you have all your wires and headers attached, I recommend coating the board with liquid electrical tape.

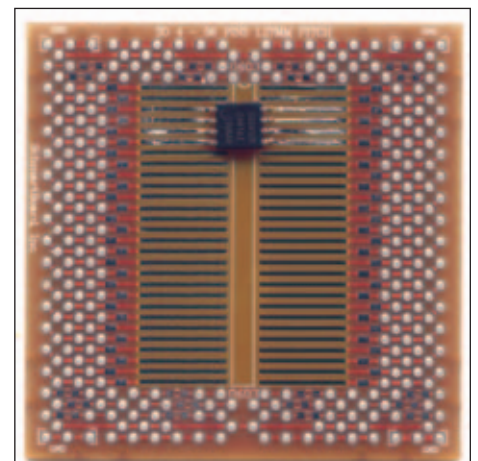
Testing the 1-Wire Wind Vane

I created an application called FEWinidDir2.exe. This program shown in Figure 12 will allow you to set the 1-Wire Rom registration for the DS2450 and test the basic operation of the vane.

The program is very fast and you can see a real-time display of the vane as it moves around. The gray area on the gauge indicates how much the vane has moved since the display was last updated.



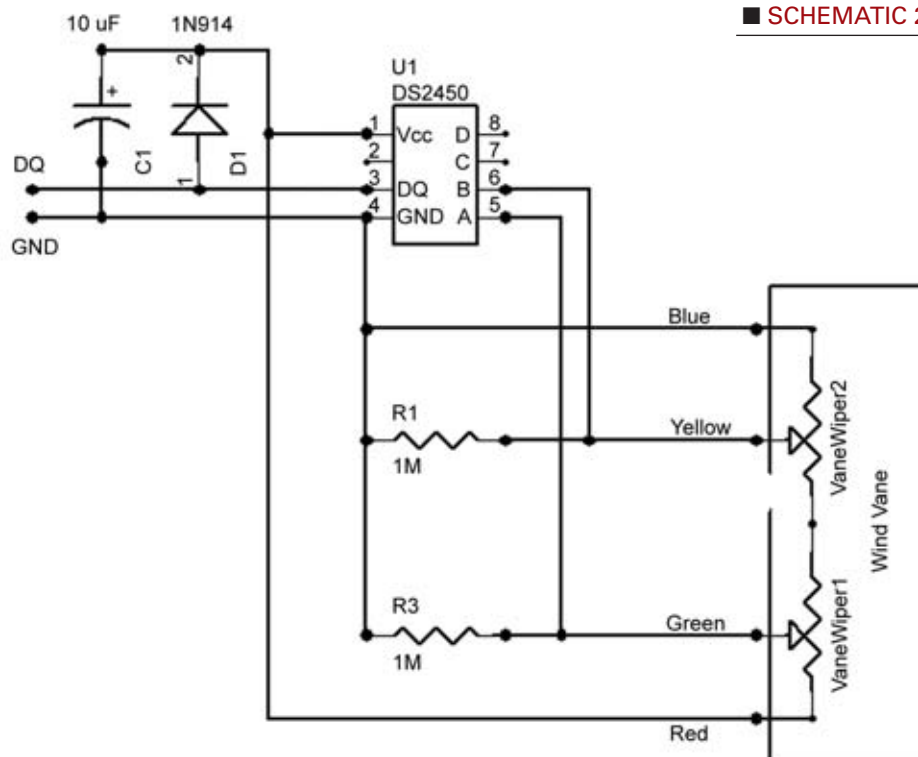
■ FIGURE 9



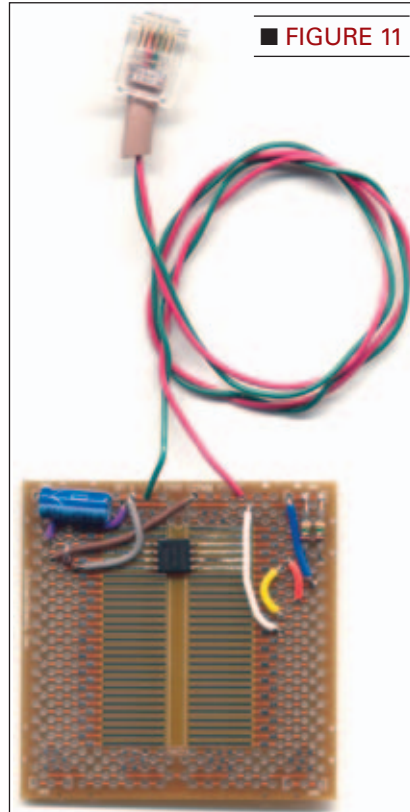
■ FIGURE 10



■ SCHEMATIC 2



■ FIGURE 11



Take a look at the source code for this program and you will see a function called `FEReDir`. This routine gets the two A-to-D readings indicating the two wipers on the potentiometer. This wind vane is unique in the sense that the two wipers in the full rotation potentiometer overlap so there

is no dead zone. When one of the wipers is in its dead area, the other wiper is used. By using a bit of math, we can then calculate a full 360 degrees at a one-degree resolution.

One of the problems I did have was that using parasite power, I could not get a full 5V voltage across the wind vane potentiometer. The best I could do was 3.1V. This was enough to take readings, but presented a problem. The routines the manufacturer supplied are designed for a full 0-5V range. I had to multiply the reading by 6.6 so that the routines would work as-is.

This particular example shows how you can create various environmental sensors using 1-Wire chips. The downside is that if you don't like working with surface-mount chips, you may find it difficult to roll your own sensors. Later in the series, we will look at using a microcontroller as our main controller/collector. This approach will allow us to use both 1-Wire and conventional means for taking measurements from various sensors. With a microcontroller, we could have simply tied two A-to-D lines to the

wind vane's potentiometer.

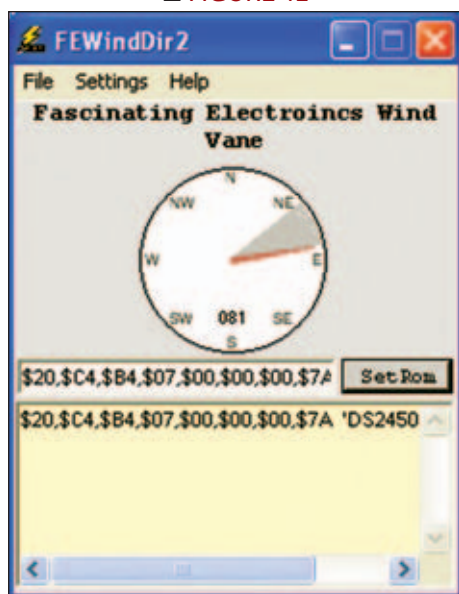
1-Wire Environmental Sensors

Let's take a look at a few more environment modules. I use the term module when a 1-Wire chip is connected to some sort of sensor and placed on a board, but you may also see the terms device or instrument.

Temperature

What would a weather station be without temperature measurements? As a minimum, you will need an indoor sensor and an outdoor sensor. You have a couple of choices, but I prefer the DS18S20 chip. I have provided chip libraries for the DS18B20, DS18S20, and DS1920 temperature chips. All can be used, but the test routines have been written for the DS18S20. The DS18S20 also has a feature where you can access the internal counter used to calculate the temperature, and by a bit of math wizardry, we can obtain a much

■ FIGURE 12



higher precision than just the standard .5C. The high-level DS1820ReadTemp function does this automatically for you.

The DS18S20 is actually marked DS1820 and comes in a TO-92 form factor shown in Figure 13. In parasite mode, the VDD lead is connected to GND. I almost always connect these chips to a length of Cat 3 cable about 4' in length. Once the chip has been connected to the cable, I dip it into liquid electrical tape as shown in Figure 14. This allows me to place the actual sensor in just about any location away from external heat sources.

Outdoor sensors must be placed in the shade and must have good air circulation. Last month, we looked at the AAG weather instrument. This instrument has a DS18S20 chip installed but when the sun hits the white plastic, the inside turns into a solar furnace. The temperature inside this furnace can vary as much as 15 degrees from the actual outside temperature.

The best way to take outdoor temperature measurements is to build a solar shield in the shape of a pagoda. The pagoda shape is created by stacking a series of bowls or plates so that they overlap. This overlap creates an area inside that is shielded from the sun.

You need at least three layers, but more are better. The pagoda in Figure 15 was created by using three plastic bowls. I cut a 1-1/2" hole in the center of the two lower bowls for the PVC pipe. The bowls are held together with 3" stainless steel bolts. The sensor is run up through the PVC pipe and extrudes through a small hole in the pipe just under the second layer.

You can buy commercial pagodas but they can run you well over \$100. This one cost me about \$1 to build. There is a simple pagoda project on the Kronos Robotics website if you want to build one of these.

Indoor temperature sensors should be placed away from windows and away from direct sunlight.

Also watch out for the heat generated by various appliances such as monitors or other sensors and power supplies. I use a small telephone surface-mount box with the sensor attached to the two front red and green wires. Be sure to drill some holes in the cover as shown in Figure 16.

To test your temperature sensor, use the TempGauge program shown in Figure 17. As before, do a Rom search, then double-click the DS1820 entry and hit the SetRom button.

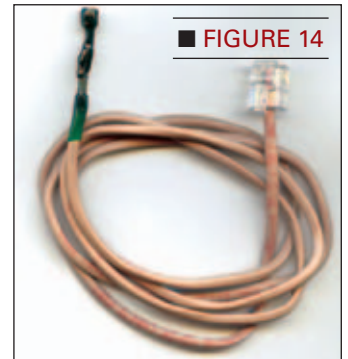
The TempGauge program will take a reading once every 800 ms and display the results in Fahrenheit. If you want to display the Celsius values, you will have to make a few changes to the source code. Just to show you what you can do with a single DS18S20 chip, I added a threshold field. When the temperature is over this value, an alarm will sound.

Humidity

You will want your weather station to keep track of both indoor and outdoor humidity. Both AAG and Hobby Boards sell a 1-Wire humidity module, as shown in Figure 18. They function almost identically and are, for the most part, interchangeable. Both



■ FIGURE 13



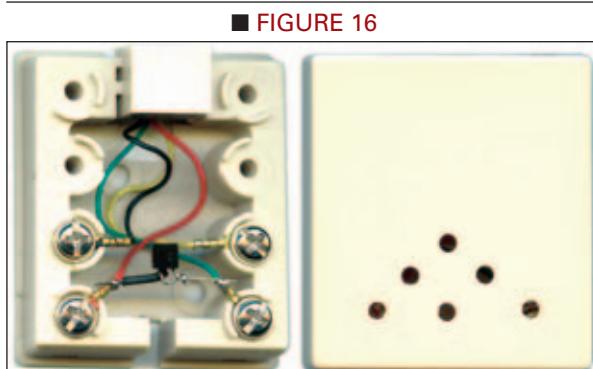
■ FIGURE 14



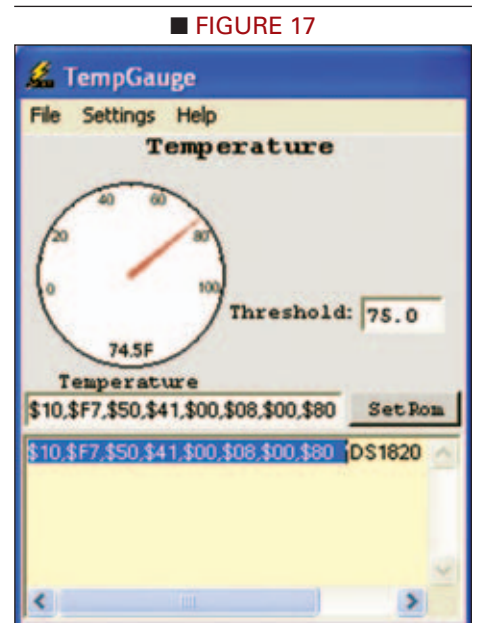
■ FIGURE 15

units utilize a Honeywell HIH-4000 humidity sensor connected to a DS2438 1-Wire chip.

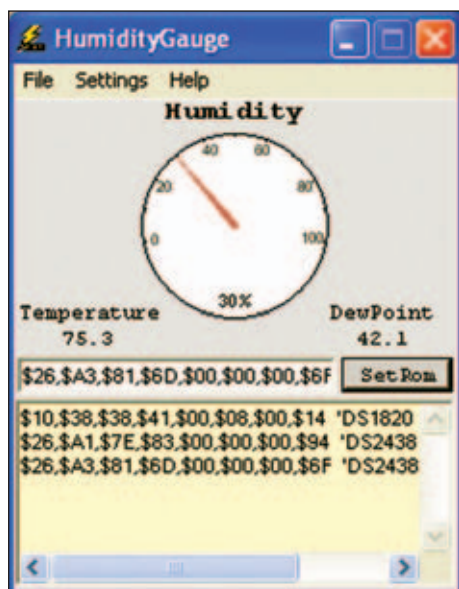
The AAG module comes in only one configuration with the case included. The Hobby Boards module comes in several configurations including kit form. I prefer the Hobby Boards



■ FIGURE 16



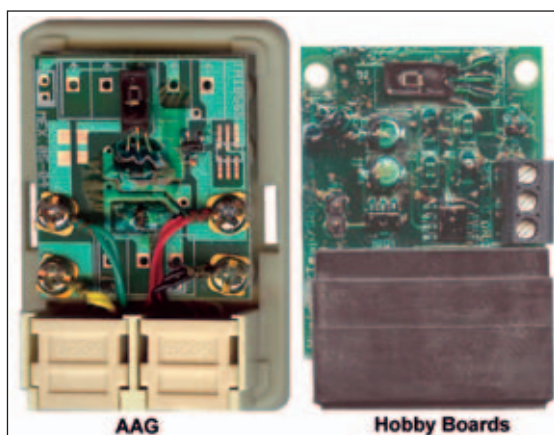
■ FIGURE 17



■ FIGURE 19

sensor without the case as it has a smaller footprint which makes it easier to mount in most utility boxes. The AAG module with the case was a bit too large for my utility box so it is used as my indoor sensor.

The DS2438 used in these modules has the capability to take temperature measurements. As long as the module has plenty of ventilation and is used in parasite mode, it is possible to use this portion of the chip as a tem-



■ FIGURE 18

perature sensor. The DS18S20 is much more stable, so I prefer to use these.

One tip that I can offer is to coat all the electronics used in your sensors with liquid electrical tape (as shown on the Hobby Boards module in Figure 18). Just don't coat the H1S-4000 sensor.

Right out of the box I found that both these modules delivered an accuracy of 5% which is better than most home gauges I tested delivered. They tracked well with my local weather station.

As before, I have provided a test program called HumidityGauge, shown in Figure 19. The program updates the display once every 500 ms.

Notice that we are reading the temperature sensor from the DS2438 chip. Once we have a temperature reading and a humidity reading, we can calculate the Dew Point. The dew point is the temperature at which the air can no longer hold the moisture that it contains. If the temperature drops below the dew point, the moisture (or dew) will be released. In some cases, this will be fog.

Later, we can combine other readings like wind speed and temperature to create a Wind Chill value.

Barometer

What would a weather station be without a barometer? Once you add a barometer to your weather station, you have the ability to predict certain weather conditions.

Again, both AAG and Hobby Boards offer a barometric pressure module, but unlike the humidity modules, they use totally different sensors and 1-Wire interface chips. At the time of the article, I had just received the AAG barometer and did not have a chance to create a test or calibration program. Once I do, I will publish the results on the Kronos website.

The Hobby Boards pressure gauge is shown in Figure 20 will not run in parasite power mode. Due to the MPXA4115A sensor used, a minimum of 14V is needed to power the board. You do have a couple of choices in powering the board. You can use a power injector provided by Hobby Boards or you can use an AC adapter. The board has its own regulator for the logic components. The board is available in kit and assembled form, and a PCB and complete schematic is also available for the do-it-yourselfer.

For barometric pressure, you can keep the sensor indoors. I have found little or no difference between indoor pressure and outdoor pressure. This is best since most of your outdoor

PARTS LIST

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- 202-0004-01 SO/SOP board
www.schmartboard.com/index.asp?page=products_so&id=54

HOBBY BOARDS

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www.hobbyboards.com/catalog/product_info.php?cPath=23&products_id=28
- DS2450 1-Wire QuadAtoD
www.hobbyboards.com/catalog/product_info.php?cPath=26&products_id=99
- DS18S20 1-Wire Temperature Sensor
www.hobbyboards.com/catalog/product_info.php?cPath=26&products_id=93
- Barometer Module (B1-R1-A)
www.hobbyboards.com/catalog/product_info.php?cPath=22&products_id=36

- Humidity Module (H3-R1-A)
www.hobbyboards.com/catalog/product_info.php?cPath=22&products_id=46

AAG ELECTRONICA

- Humidity Module (TAI8540D), Pressure Module (TAI8570)
www.aagelectronica.com/aag/en-us/dept_2.html
- AAG Weather Instrument (TAI8515)
www.aagelectronica.com/aag/en-us/dept_1.html

FASCINATING ELECTRONICS

- Standard Anemometer Kit (WEA-WVKIT)
www.fascinatingelectronics.com/weatherinst.html

OTHER

- RJ11 Surface-Mount Box — I used a GETL26101. These can be purchased from most home centers.

sensors will be used in parasite mode.

I found this module to be very accurate, and once calibrated, tracks the local weather station readings within 2%. Hobby Boards calibrates the module for you when you place your order but you may need to calibrate the module again once it is installed into your weather station. The test program BarometerGauge shown in Figure 21 has a built-in calibration wizard, so calibration is a breeze.

Notice in the test program I am displaying the DS2438 temperature reading. It runs a bit high due to the onboard regulator so I don't recommend using it for anything but monitoring the board temperature.

In order to predict any kind of weather with a barometer, you need to keep track of your readings over time. Later in the series, we'll tie all the sensors to a single program that will do just that.

Other Sensors

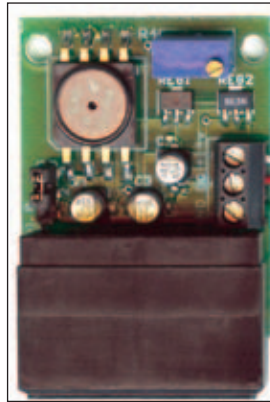
There are myriad sensors you can add to your weather station. As this series continues, we will look at some of these. I will also be writing small application notes for them and placing them on the Kronos weather forum at www.kronosrobotics.com/forums/.

Going Further

You may have noticed that we only talked about individual sensors and not a weather station as a whole. Many of the sensors can work together to give us calculated readings like wind chill and heat index. Near the end of the series we will look at display systems and ways to plot long term data.

For now, it is important that you get the individual sensors working. Later, I will show you how to use a microcontroller to collect and display your data. The display system you choose and the collection method will dictate how your weather station is built.

Next month, we are going to put our weather station aside and look at home automation. I will show you how to interface to three different X10 controllers. If you decide later to tie the home automation system into your weather station, the type of controller you use as your interface will also play a part in how



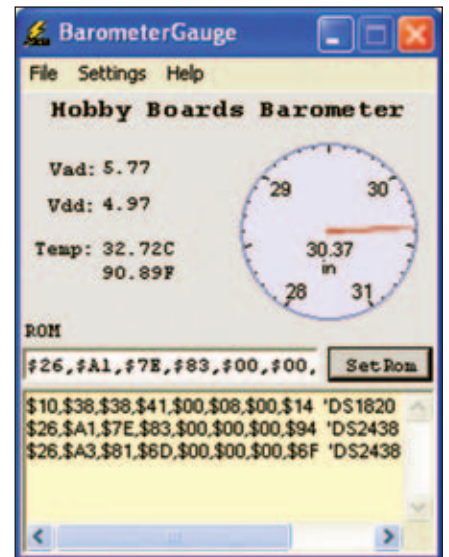
■ FIGURE 20

your station is built.

As you can see, there are a lot of variables and no two weather

stations are alike. Don't worry. Part of the fun is tearing down the station and rebuilding it in a new and better configuration to suit your needs.

All the example programs, as well as the source, are available for download at www.kronosrobotics.com/Projects/esensors.shtml. **NV**



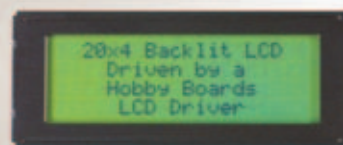
■ FIGURE 21

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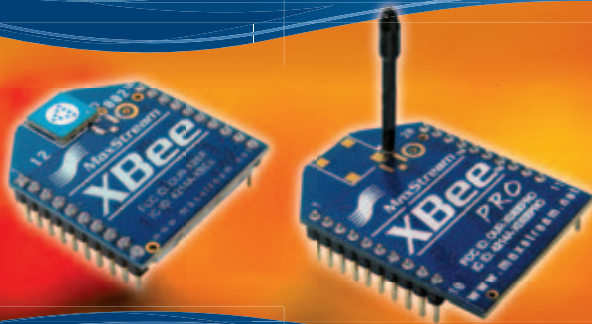
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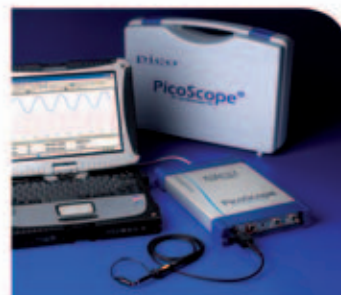
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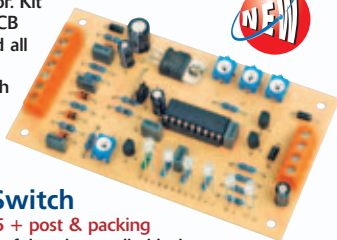
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Speedo Corrector MkII

KC-5435 \$29.00 + post & packing

When you modify your gearbox, diff ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. With this improved model, the input set-up selection can be automatically selected and it also features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components with clear English instructions.



Improved Model!

DC Relay Switch

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An extremely useful and versatile kit that enables you to use a tiny trigger current - as low as 400µA at 12V to switch up to 30A at 50VDC. It has an isolated input, and is suitable for a variety of triggering options. The kit includes PCB with overlay and all electronic components with clear English instructions.



Powertool Battery Charger Controller

KC-5436 \$23.25 + post & packing

Cordless drills are fantastic & cheap but, the batteries in them don't last with the simple charger supplied. This controller turns the cheap charger into a contractor grade intelligent charger. It incorporates charge timeout, min and max temperature monitoring, Delta V charge detection, power and charge LED indicator and more! Suits both Ni-Cd and Ni-MH cells. Kit includes PCB with overlay, case and all electronic components.



Uses existing charger!

Battery Zapper MkII

KC-5427 \$58.00 + post & packing

This kit attacks a common cause of failure in wet lead acid cell batteries: sulphation. The circuit produces short bursts of high level energy to reverse the damaging sulphation effect. This new improved unit features a battery health checker with LED indicator, new circuit protection against badly sulphated batteries, test points for a DMM and connection for a battery charger. Kit includes case with screen printed lid, PCB with overlay, all electronic components and clear English instructions. Suitable for 6, 12 and 24V batteries. • Powered by the battery itself



Improved Model!

Magnetic Cartridge Pre-amp

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This kit is used to amplify the 3-4mV signals from a phono cartridge to line level, so you can use your turntable with the CD or tuner inputs on your Hi-Fi amplifier. The design is suitable for 12" LPs, and also allows for RIAA equalization of all the really old 78s. Kit includes PCB with overlay and all electronic components. • Requires 12VAC power



As used in the Beach Boys classic hit 'Good Vibrations'

Requires 9-12VDC wall adapter (Jameco #252751 \$12.05)



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Note: Products are dispatched from Australia, local customs duty and taxes may apply.

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• Requires 9V battery



Theremin Synthesizer MKII

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By moving your hand between the metal antennae, create unusual sound effects! The Theremin MkII improves on its predecessor by allowing adjustments to the tonal quality by providing a better waveform. With a multitude of controls, this instrument's musical potential is only limited by the skill and imagination of its player. Kit includes stand, PCB with overlay, machined case with silkscreen printed lid, loudspeaker, pitch antennae, all specified electronic components and clear English instructions.



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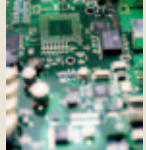
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Electronics



Every bench needs a power supply to fully complement the rest of its test equipment.

I consider this to be just below the DMM in essential test equipment. The question arises, though, as to what type of supply and what features should be incorporated so as to make it as universal as possible.

A TEST BENCH POWER SUPPLY

I have designed and built a dozen different power supplies over the years, but recently I built the one presented in this article. It is the culmination of many years on the test bench, which I feel will cover most situations without going to ridiculous extremes.

When I started this design, I set down certain parameters that I thought were necessary and threw out some that I felt were of too limited use to warrant the extra circuitry and expense. I based these decisions on previous supplies I had built. Some of my objectives were the following: smallest physical size possible so as to take up minimum bench space; separate analog and

digital supplies with floating grounds; at least two analog supplies with easily variable voltage; full metering on both these supplies; and last but not least — good regulation and stability.

The final design came out something like this: dual 0-20V @ 1A; 5V fixed @ 1A; no-load/full-load regulation <10 mV; RMS ripple < 0.5 mV; and simultaneous voltage and current metering on both variable supplies. This gave the capability for design/repair of all low power control circuits, but still have enough “oomph” for mid-power circuitry.

From previous experience, I have found that dealing in high-power circuits (which doesn’t occur that often), the requirements for that power are all over the place. It would be difficult and expensive to design a supply to handle all these situations. At present, I have only one high-power supply — a 150 watt, 13.2V unit for standard mobile use (auto, marine, etc.). For the occasional circuits that I build under the high-power heading, I construct a supply just for that device and its particular needs.

Since all outputs are floating with respect to grounds, this can be set up for \pm supply voltages (my preference) for analog circuitry and still have a digital 5V source



available. Also, all the supplies can be “series-ed” together to provide over 45V at one amp for higher power when needed.

Because of limited panel space due to the unit’s relatively small size, I deleted some features that others might consider essential. One of these was current limiting. I have rarely experienced much benefit from this. Whenever I have accidentally shorted something on the breadboard, usually the discharge of ‘onboard’ capacitance will burn a device out in short order. With dual metering for voltage and current, I can constantly monitor this when the circuit is powered up. Upon initial power-up or any circuit changes thereafter, I can slowly bring up the voltage to the desired level while monitoring the current for unusual excess. As far as protection to the power supply itself, the IC regulators have built-in overload and thermal shutdown.

In the past, my designs have incorporated a lot of discrete circuitry for regulation, etc. Since this unit would have a maximum rating well within the capabilities of readily-available IC regulators on the market, I decided to check them out as to their claims. They all lived up to their specs and performed as well as anything I had designed previously. Their only shortcoming was the lack of provision for remote voltage sensing, but I figured I could live with that by up-sizing my connection leads and the fact that I would only be dealing with a maximum of one-amp loads.

This article will deal with the power supply as built, but will also be interjected with a lot of options and general guidelines for power supply design. To start with, I had the option to go with a linear design or a switch-mode design. The linear design pros are, in general, better line/load regulation and less ripple. The switchmode pros are better efficiency and less weight. The advantages of the switcher were of no consequence here, as we do not need mobility or great

efficiency in this situation. The last thing one needs on a test bench is a source of EMI, which the switchers are prone to produce!

For the analog supplies (0-20V), I chose LM317K regulator chips with a TO-3 case for improved heat transfer ability (more on this later). Most of this design is pretty much right out of the book and you can Google LM317 (head for National Semi on this page) for a lot of additional information. The 5V fixed supply is based on simple 7805 design.

Theory of Operation and General Guidelines

Most of this discussion on circuit theory, options, and some general guidelines in linear power supply design will refer to the schematic in Figure 1. To begin with, the heart of the supply is the main transformer(s). Once the required output voltage and current are determined, design of the raw B+ section can proceed. In this unit, I wanted slightly over 20.0 volts at a full load current of one amp coming out of the regulator chip (LM317). These regulators need a minimum of three volts across them (Vin-Vout) for proper operation. The valleys of the input ripple plus the average DC must remain high enough to support the regulator’s required three-volt differential, and puts the most strain on the raw B+ at full load current. Also, one must consider line voltage sags which further necessitates an increase in raw B+ to cover these situations.

All these factors that require an increase in raw B+ for reliable operation are known as “headroom.” Headroom is the available B+ (pure DC component) under worst-case conditions as compared to the B+ needed under ideal conditions. Regulators love a lot of headroom to cover all situations encountered and still operate reliably. Regulators also hate a lot of headroom due to the increased voltage across them, which increases wattage dissipation, which

increases internal junction temperature and, if it goes high enough, could eventually destroy it. So, as is the usual case with electronic designs, we are faced with tradeoffs.

In this supply, I have stated that we need 20 volts of regulated output plus a minimum of three volts differential under any load. This supply also has an RMS ripple of 0.6 volts at full load. That means the negative peak ripple ($1.41 \times \text{RMS}$) will dip the average B+ by 0.85 volts. We also still have to consider line voltage sags. These days, power line voltages are pretty stable, so I only allowed for a 5% reduction here. Adding all these factors (differential, ripple, and line sag), we need 25.0 volts for worst-case conditions, which would be under full load current, in regards to raw B+. In transformers of the VA range used here, the voltage would rise about 20% under no load conditions and will produce a raw B+ of 30 volts at that point. This is the minimum headroom at idle.

A general rule-of-thumb when designing full wave rectifiers that are feeding a capacitive input circuit is to size the transformer secondary current at 1.5 times the filter capacitor’s average DC output current. This is due to the high charging currents needed to maintain the capacitor at peak or near peak voltage. Assuming a one volt drop (or two volt for bridges) across the full wave rectifier, we need a peak voltage of 31 volts to each rectifier from the secondaries. This would require a transformer secondary of 22 volts RMS (44 volt center tapped) and a current rating of 1.5×1 amp (the DC output current) or 1.5 amps.

I was fortunate to have salvaged one of these transformers from one of my obsolete supplies — a 120V primary with a pair of 44 volt center tapped secondaries at 1.5 amp each. Although these transformers are available, you may find them pricier than the common ‘garden variety’ 24 volt secondary ones. With these (assuming you couldn’t find a 48V with a center tap), you can substitute

zero volts, this voltage has to be cancelled. This is where Z1 comes into play (a precision 1.225 volt Zener) by developing an almost exact voltage of opposite polarity. Its circuit consists of negative half wave rectifier D3, filtered by C2 and current limited by R4.

Now, when P1 and P2 are at zero, a negative 1.225 volt level is presented at the current source point and adding this voltage to the positive 1.25 volt constant of the regulator equals zero volts on the output or nearly so. On my unit, I have 0.015 volts and 0.019 volts, respectively, on the variable outputs at "zero" setting. Going back to the voltage adjusting pots P1,P2, their values are determined by two things: the desired output voltage of the regulator and the constant current source. Again, I'll use this unit as an example.

The constant current was set at 5.2 mA as previously described. Also, since I am taking the low end of the adjustment string to a -1.225 volts which almost nullifies the regulator's constant of +1.25, the output voltage will track the exact voltage drop across P1 and P2. For a maximum output voltage of 20.0 volts, we need a 20.0 volt drop across P1,P2 and — according to Ohms law — $R=E/I = 20/0.0052 = 3850$ ohms total.

From past experience, I knew that a single turn pot would not give a smooth enough voltage adjustment for this great of range. It would need about 10 times as much travel for smooth transitioning. I was faced with two choices: a 10 turn adjustment pot or two pots with a 10:1 ratio. A 10 turn pot is too expensive and time-consuming for repeated adjustments, so the combo unit was the clear choice here. These pots should have a resistance ratio of about 10:1. I chose 5K and 500 ohms based on the resistance calculated. In practice, the fine pot is normally left at its midpoint and then tweaked after the coarse pot has set the approximate output desired. This now allows for a fine adjust of ± 1.25 volts — a very optimum span.

With the fine adjust pot (500 ohm) set at its midpoint and putting 250

ohms into the resistance string, this is subtracted from the 3,850 ohm total previously calculated and leaves us with 3,600 ohms to add for P2. Since the nearest standard pot is 5K, it will have to be shunted to attain the value we need. This is accomplished with R5 (12K) and is calculated based on a 5,000 ohm pot. Bear in mind, most pots have a $\pm 20\%$ tolerance and R5 will have to be adjusted as required (hence, the asterisk on R5).

With P2 (coarse) at maximum and P1 (fine) in its mid position, the voltage output will be 20.0 volts, and P1 will allow for a fine adjust of ± 1.25 volts throughout the total range. With P1 and P2 set at minimum, the voltage output will be zero or nearly so. One additional note is that there is a small error current flowing through the P1,P2 string and into the regulator's adj. pin. This is approximately 50 μ A and has been omitted from prior calculations for simplification and because it is of little consequence here.

C3 is added for input bypassing and stability insurance. D5 is a protection diode and will shunt any external capacitive discharge around the regulator rather than through it; in any event, causing a more positive voltage on the regulator output than its input. C4 gives much improved ripple rejection and D6 prevents unintentional C4 discharge through the IC, again shunting these currents around the regulator via D5. C5 and C6 are added for improved transient response.

As for the LCD panel meters, I selected the smallest I could find (but still maintain adequate character height for readability) due to limited front panel space. They are all 200.0 millivolt meters. The voltmeters are set up for 20.00 volt operation by proper decimal location and input scaling. R7, R8 are the scaling resistors and P4 is added for calibration. These trimmers are small and cheap and are much more accessible than the panel meter's internal calibration pot.

The current metering presented a small problem. I wanted to measure 0-1 amps in milliamp steps. This equates to 100 μ A/mA since this is a basic

200.0 mv voltmeter (no decimal display is used here). The shunt required for this conversion is 0.1 ohms (R1). I could not add this into the positive output line as there is no provision to keep it in the regulator's feedback loop.

This would have presented an increasing regulator load current error. For that and other reasons, I did not want it in the negative output either. However, it could be added ahead of the regulator where its voltage drop would be of no consequence. That location presented one other problem though, and that was, even with no load current, there is still the regulator quiescent current of 5.2 mA flowing through this point. This had to be dealt with as even with a 5 mA load current, the meter would show over 10.2 mA — a 100% error at this point.

The solution was to offset the quiescent current and that is the function of R2, R3, P3. Since 1 mA is read for every 100 μ V developed across the shunt, a negative 520 μ V offset had to be applied to the panel meter's positive input lead. The values of those components provide just that, so that at no load the quiescent current is exactly cancelled out giving a meter reading of 0.0 mA.

Even though the raw B+ voltage sags at full load and introduces an error in this divider string, it only amounted to a 1 mA error at the full load of 1,000 mA. This error is far beyond the panel meter's accuracy and can be ignored. The second variable supply is not shown in detail on the schematic because it is a carbon copy of the first one. Just bear in mind, you will need double the components shown to complete both supplies. A diode (D4) to power a 14V LED panel light is attached to one of these supplies to indicate DC power on/off. You will notice I have incorporated a four pole-single throw switch for all DC supplies and the indicator light. When I switch off DC power to a circuit, I want just that — no power! By merely switching off AC power, there is a bleeding off DC voltage present at the panel jacks. This could hang on a long time for light loads.



Other reasons for separate AC and DC power switches are to eliminate transients presenting themselves at the front panel jacks upon AC power up/power down, which can occur at the first few milliseconds of AC switching.

Another reason is that when using a negative reference voltage such as Z1(-1.225V) for the regulator and due to unequal charge/discharge times of C1, C2, a 1.5 volt step-up in voltage can occur upon AC shutdown only. This is not an easy problem to overcome to cover all situations. Again, DC switches block this undesirable occurrence.

All my power supply designs have incorporated separate AC and DC switching for these and also to give you a setup procedure while the DC power switch is off, as the metering will still be active. If one were to just drag this supply to the test bench for a

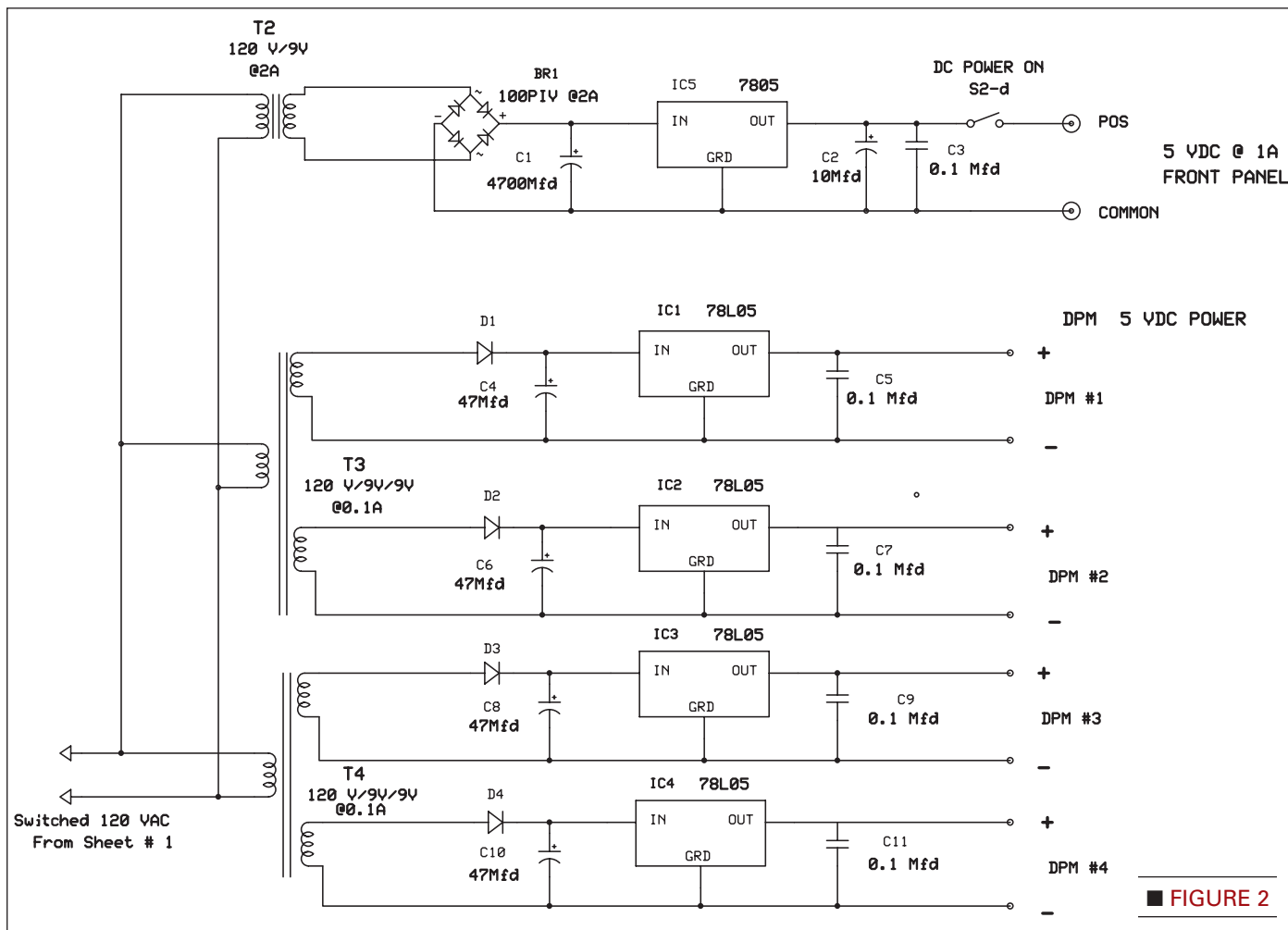
couple of hours at a time and then return it, there really wouldn't be any need for an AC switch — just plug and go! But for my use, this supply will become a permanent fixture on my test bench, so I decided it needed AC switching.

Let's discuss the five volt supplies that are shown in Figure 2. There are five of these, but it's not as bad as it sounds. There are some options here. The first of these is the 5V at 1A front panel supply. This is so straightforward, it almost needs no explanation. T2, BR1, C1 provide raw B+ to the regulator chip IC5 (7805), which then does a fine job of regulating it to +5 VDC. T2 has a single 9 VAC secondary at 1.5 amps and was chosen for minimum voltage differential across IC5 for reduced wattage dissipation.

The other four five-volt supplies are for the four front panel meters.

These are all meters requiring isolated power supplies. Two of these supplies could be eliminated for the front panel voltmeters, since the meter's negative input is connected to common. A 78L05 (TO-92 case) could be connected to the raw B+ supply and power these meters directly from its positive and common. You will need one of these for each supply you are metering. The meters will have to be the type that operate with common grounds (negative input lead and negative power lead tied to common).

Another option is to use only one meter per supply and switch them from volts to amps, with regards to their input leads. These will require isolated power supplies, but only two instead of four. I have to admit that the meters used in this project are by far the greatest cost of constructing it. I wanted the luxury of full metering all



■ FIGURE 2

the time, however, and wouldn't have done it any other way.

The four supplies for these meters take up very little room and the total cost for all the components required was just over \$5. These supplies need only half wave rectification and little filtering since load requirements are on the order of 5 mA each.

Construction

I built this unit as small as possible, but you may want to open up the overall dimensions slightly. The power supply's overall dimensions are 9" wide x 3-1/2" high x 6" deep. If you alter the design, lay out all your parts first to get specific measurements for cabinet clearances and dimensions needed before starting construction. When I make up an enclosure for circuits requiring a fair amount of heat dissipation, I usually build it as follows (see Figure 3).

The bottom and back are made of one piece of 1/8" aluminum sheet. A 90 degree bend is formed at the intersection of the bottom and back. In my case, this was a sheet 9" x 9-1/2" with the 90 degree bend 3-1/2" from the long end. This part of the enclosure will also double as the heatsink, eliminating a lot of expense and clutter. Pop rivet three 1/2" aluminum angle brackets to the sides and front of this base, flush with their edges. (In my unit, these were two 6" lengths and one 3-3/4" length.) These will be the attachment points for the front panel and top cover.

Next comes the front panel. This was a piece of 1/16" aluminum cut to 3-1/2" x 9". Lay out mounting holes at the bottom and transfer these to the front angle bracket on the bottom plate. Drill and tap these for the front panel mounting screws.

Next, the metal cover is formed. Mine was 16" x 6-1/2" with two 90 degree bends, 3-1/2" from the long ends, to form the sides. The 6-1/2" dimension gives the cover a little overhang on the front and back of the enclosure. Drill two mounting holes at the

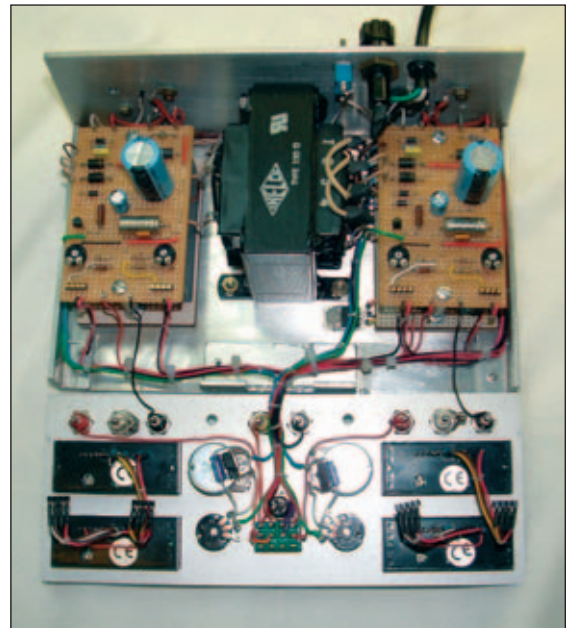
bottom of each side. Align the cover to the base and transfer those holes to the side angle brackets. Drill and tap these for the cover mounting screws.

Some fitting may be necessary as you are constructing this. Disassemble and then later paint it the color of your choice, but do not paint the 1/8" bottom sheet. Add four feet (can be self-adhesive) and the basic enclosure is done. Strong, functional, attractive, and simple, to boot!

At this point, the major components can be installed. Make sure you have allowed ample room and clearance in regards to overall dimensions for the components you have selected. I installed the main power transformer (T1) in the rear center of the bottom plate. This is a logical mounting point and gives the unit good balance. On either side of T1 are two circuit boards spaced and stacked on standoffs, and measuring 2-3/8" wide x 3-1/2" deep. (That will be four boards total.) To the left side of T1 is the five volt panel supply transformer T2, a low profile type mounted to the bottom board. Standoff mounted, the upper board is one of the 0-20 volt (A) boards.

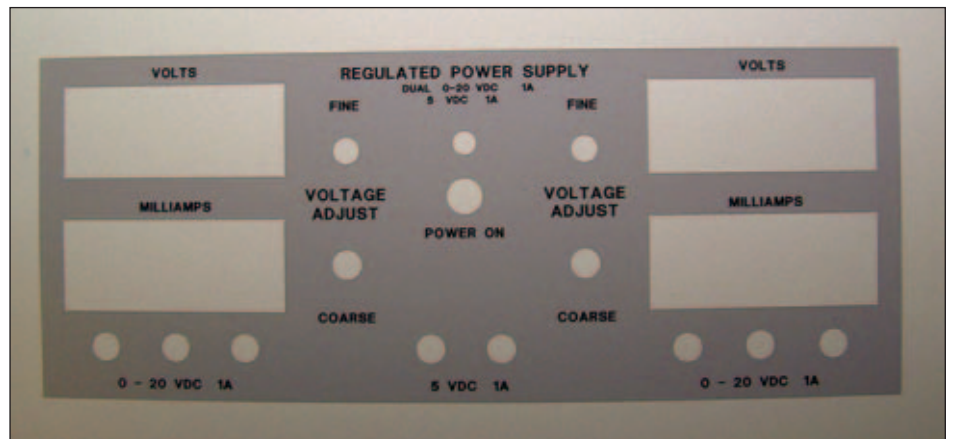
To the right side of T1 are the five-volt supply regulators along with T3, T4, and is the bottom board. As with the left side, the mounted standoff is the other 0-20 volt (B) board. The rear

■ FIGURE 3



panel receives two LM317K ICs mounted directly behind their respective regulator boards. The 7805 (IC5) chip is mounted to the bottom plate near the front left hand corner of its regulator board. F1, S1, and the line cord input are mounted through the back panel wherever it's convenient. The front panel components should be laid out in a nice symmetrical order and then machined. Watch for clearance here to interior components!

For front panel labeling, I have been experimenting with various escutcheons. Recently, I have been using some of the CAD programs from PC and front panel manufacturers. Any CAD program will work as long as it gives you a reference point, precise layout cursors, and the ability



■ FIGURE 4



to add text. For this panel, I used the free CAD program (Front Panel Designer) from Front Panel Express LLC (an advertiser in N&V, which can be downloaded from the web) to lay out and label it. From there, you have two choices: immediately email this to the manufacturer for production or make up your own.

Figure 4 shows the escutcheon I made up from the CAD program. One click of a tool button and you can hide lettering and show layout points for machining the panel. These files will print out to exact dimensions. When I make my own escutcheon, I print out the image of Figure 4 to matte photo paper and then double coat it with Krylon Crystal Clear Finish. Let dry and apply to the front panel with 3M spray adhesive. Hole trim out can be done before or after. For this project, I treated myself and had the manufacturer make up the panel. Pricey, but they do one beautiful job. However, the photocopy method does produce a very professional front panel look, especially with black print on a natural aluminum background.

One last note — the particular panel meters I used were chosen for their small panel mount size since panel space was at a premium. I also chose these with the isolated power option. For some reason, I seem to get better low end stability with isolated power supplying these meters. A 4 pin SIP header was connected to the meter leads via 3" #24 gauge wires, and a matching 4 pin SIP socket was soldered to the front of the board. This gives easy install/removal of the front panel.

Heatsinking Details

Any article on linear power supplies would not be complete without some discussion on heatsinking. A lot of readers are aware of the need for heatsinking but are not familiar with the details of requirements. Heat transfer — as simple as it sounds — can be an extremely complex science, so I will try to keep this discussion simple.

To begin with, all materials have a

given rate of heat transfer, which is their ability to dissipate heat generated within them. This ability is known as thermal resistance and is shown as the Greek symbol theta (θ). This will be shown here as T_r (thermal resistance) and actual temperature as T . The lower this quantity is, the lower the T_r , and hence, the greater rate of heat transfer. The rating is given as degrees C/Watt and is the rise in temperature in degrees Centigrade for one Watt of dissipation within a given object. The lower the number, the better the dissipation factor. A loose electronic analogy would be the discharge rate in an R/C circuit, with charge being analogous to heat and R representing T_r . The lower the R is, the more rapid the discharge rate or heat dissipation is.

We start our calculations with the manufacturer's maximum rating for a semi's junction temperature. For almost all commercial grade semiconductors, this will be 125 degrees C (150 for military). This means that even operating at worst-case conditions, we must keep that device under that temperature, preferably under 100 degrees C (100 C is not always possible or practical).

Two factors dominate the semiconductor junction temperature rise: the wattage developed across the device and the T_r to the ambient air surrounding it. I will use this supply as an example. The first hurdle we must cross is the T_r of the junction to its case. This is noted as T_{r-j-c} . I chose the TO-3 version of the LM317 because it has a lower T_{r-j-c} than the TO-220 package. The manufacturer specifies a T_{r-j-c} of 2.3 degrees C/W. This means that for every watt of dissipation at the junction, the case temperature will rise by 2.3 C. We always want to look at the worst case here to determine maximum temperature rise. In this example, I will use a near worst-case example of five volts output at a one amp load. The raw B+ at this point is approximately 25 volts, and by Ohms law, we have $25V-5V \times 1.0 \text{ amp}$ or 20 Watts of heat dissipation within the regulator chip. The 317 case tempera-

ture will rise to 2.3 degrees per Watt or 46 degrees C for our 20 W. This is a given we have to live with, but from this point on, we do have some control.

The next hurdle to cross is the T_r of the insulating material between the case and its mounting surface. This is noted as T_{r-c-s} (thermal resistance of case to heatsink). This is almost zero if the case is mounted directly with no insulator. If the case is not electrically isolated from the chip, we have to use an insulator, as is the situation here. I used mica insulators and high quality thermal grease, in which the manufacturer specifies a T_r of 0.35 C/W.

One word of caution — NEVER use production type self-adhesive insulators as they are terrible and seem to perform even worse with thermal grease. Also, I would like to mention at this point that the heatsinks mounting surface should be perfectly flat with no burrs from drilled holes. When insulated like this, mounting is achieved the easiest with nylon screws and nuts.

The last hurdle to cross is the T_{r-s-a} (thermal resistance of the heatsink to ambient air surrounding it). Up to this point, we have a T_{r-j-c} of 2.3 C/W and a T_{r-c-s} of 0.35 C/W for a total of 2.65 C/W and a semiconductor dissipation of 20 W. The temperature rise at the heatsink point-of-contact will be $2.65 \text{ C} \times 20 \text{ W}$ or 53 C. Conversely, the semiconductor junction will be 53 degrees C hotter than the heatsink at this point, and if we were running the part at the maximum temperature of 125 C, that means this contact point would now be $125 \text{ C} - 53 \text{ C}$ or 72 C.

Bench test equipment is normally used in an environment not exceeding 25 C (77 F) and this is as low as the heatsink temperature can go. The heatsink cannot be allowed to rise in temperature more than 47 C (72 C - 25 C) in order to maintain the maximum junction temperature. Heatsinks are rated by their thermal resistance T_{r-s-a} (sink to ambient air) which is given as degrees C/Watt. Since we are dealing with 20 W and plugging this into the formula, we have $47 \text{ C}/20 \text{ W}$

or 2.35 C/W. This is the minimum heatsink T_r we can get away with. In practice, we would want a heatsink with less T_r for a greater margin of safe operation, probably on the order of 1.5 C/W. This would reduce the maximum junction temperature to 108 C for worst-case situations.

From here, you would look up a manufacturer's heatsink for this rating and it would probably be fairly sizable. Also, you need one for each 20V supply. As a matter of interest, the manufacturer cautions against too much heatsinking on the 317 so that they can reach their thermal shutdown temperature when normal overload occurs.

From past experience, I knew the heatsinking capabilities of the chassis used in this unit would be adequate, so I didn't bother with precalculations. Post construction tests bore this out by measuring case temperatures at near worst-case for the variable supplies running individually and normal case tests with all supplies running concurrently.

These tests were at full load current and case measurements taken after one hour of operation. The junction temperature was computed by the case temperature, T_r j-c and wattage (20 W) to arrive at a figure for this. The variable supplies were about 115 C, which is just about perfect in regards to overload vs. thermal shutdown. The five volt fixed supply was at 69 C. Even though the TO-220 case of the 7805 has a higher thermal resistance, it runs with much less wattage across it, hence the lower junction temperature.

With all supplies running concurrently at 20V-5V-20V and series up to a one amp load current, the junctions were 65 C - 80 C - 65 C, respectively. This is well under the maximum operating temperatures of 125 C. These were tested with the cover in place and with no ventilation holes. I may add vents at a later

date, which would undoubtedly improve these readings.

The current rating on this unit is very conservative and will actually output closer to 1.5 amps, before dropping out of regulation. However, it wouldn't be advisable to do this at low voltage settings for more than a couple of minutes due to heat dissipation. At higher voltage settings, it can be longer (it all relates back to headroom).

Conclusion

This supply has been in service for several months now, and has performed flawlessly. It has also been very user-friendly. If you do not currently own a bench supply, build this one. After a few usages, you will wonder how you ever got along without one. I hope that even if you don't build this unit, you will have gained some helpful pointers that will be of use in similar projects. **NV**

PARTS LIST

0-20 VOLT BOARDS

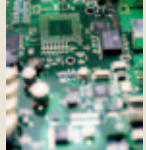
	DESCRIPTION
<input type="checkbox"/> T1	120V primary, dual 44V center tap secondaries @ 1.5A
<input type="checkbox"/> D1,2	3A, 100 PIV
<input type="checkbox"/> D3,4,5,6	1N4002
<input type="checkbox"/> C1	4700 μ F/35V *
<input type="checkbox"/> C2	100 μ F/35V *
<input type="checkbox"/> C3	0.22 μ F
<input type="checkbox"/> C4	10 μ F/35V
<input type="checkbox"/> C5	22 μ F/35V
<input type="checkbox"/> C6	0.1 μ F
<input type="checkbox"/> R1	0.1 Ω 1% 3W
<input type="checkbox"/> R2	16 Ω
<input type="checkbox"/> R3	750K
<input type="checkbox"/> R4	2.7K
<input type="checkbox"/> R5	12K *
<input type="checkbox"/> R6	240 Ω 1%
<input type="checkbox"/> R7	100K
<input type="checkbox"/> R8	910 Ω
<input type="checkbox"/> P1	500 Ω
<input type="checkbox"/> P2	5K
<input type="checkbox"/> P3	200K (Mouser #531-PT10V-200K; \$0.42; www.mouser.com)
<input type="checkbox"/> P4	200 Ω (Mouser #531-PT10V-200; \$0.42)
<input type="checkbox"/> Z1	1.25 volts reference (Mouser #511-TS821A1Z; \$0.64)
<input type="checkbox"/> IC1	LM317K (Mouser #511-LM317K; \$2.10)

FIVE VOLT SUPPLIES BOARD

<input type="checkbox"/> T2	120V primary, 9V secondary @ 1.5A
<input type="checkbox"/> T3,T4	120V primary, dual 9V @ 65 mA secondaries (Mouser #838-SB2812-1218; \$1.30)
<input type="checkbox"/> C1	4700 μ F/16V
<input type="checkbox"/> C2	10 μ F/16V
<input type="checkbox"/> C3,5,7,9,11	0.1 μ F
<input type="checkbox"/> C4,6,8,10	47 μ F/16V
<input type="checkbox"/> BR1	2A, 100 PIV
<input type="checkbox"/> D1,2,3,4	1N4002
<input type="checkbox"/> IC5	7805
<input type="checkbox"/> IC1,2,3,4	78L05

MISCELLANEOUS

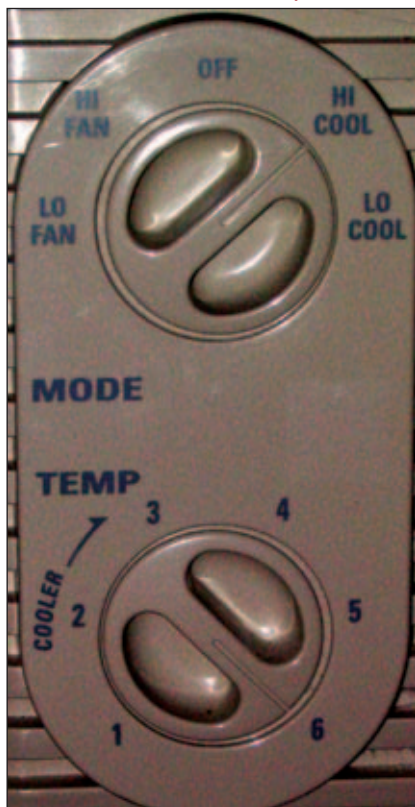
<input type="checkbox"/> S1	SPST toggle switch
<input type="checkbox"/> S2	4PST toggle switch
<input type="checkbox"/> Panel Meters	200.0 mV (CX101B; Cat #12206 ME; \$13.50) Marlin P. Jones and Associates (www.mpja.com); also available at Circuit Specialists (www.circuitspecialists.com)



The summer of 2006 was brutal due to the heat and humidity.

Air conditioning was needed to make it bearable. In my view, the need was greatest during the night when I wanted to sleep. The controller I had assembled two years ago for the window-mounted A/C worked admirably. I wanted to share it with others who may have a similar need.

■ **FIGURE 1.** View of the A/C controller with minimal functionality.



BEAT THE HEAT WITH THIS EXTERNAL A/C CONTROLLER

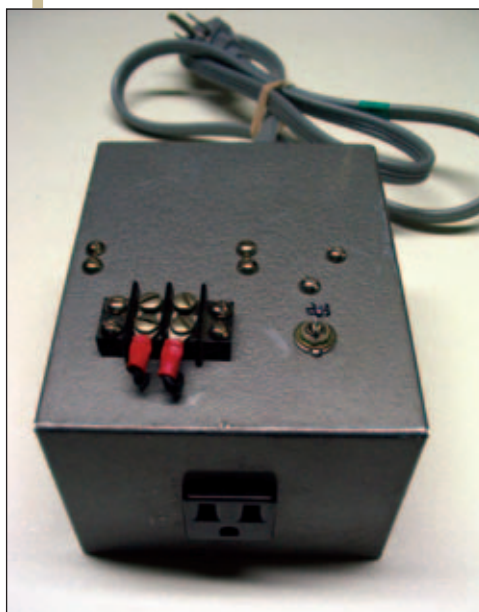
My window-mounted air conditioner has one big drawback: the temperature that it maintains in the room is not constant. The problem can be traced to the simple temperature sensor that is built into the A/C. There is no setting for a given temperature; it is just marked "cooler 1 through 6." There are two fan speeds and an option to have the fan running all the time or just when the compressor comes on-line. (Refer to Figure 1 for a view of the A/C controls.)

Regardless of the setting, it may run or not run depending on whether sunlight is hitting the unit. It

also seems to respond to the difference between the inside and outside air. For example, the room air may be warmer than the outside air. The A/C will not run unless the setting dial is turned to the coldest point and the fan is turned on. Eventually, it gets the message and turns on the compressor.

Since the A/C is in my bedroom, I want it to cool down the room before I retire. I also want the room to be cooled during the day, but not to the same extent as at night. To achieve these goals, I found myself constantly tweaking the control knobs. This is not possible when one is away from home. Why don't I turn it off during the day? The reason is simple – the room heat soars and the time required to cool it down is excessive.

I solved my problem by building an external controller for my A/C. I found an inexpensive wall thermostat that has an A/C option. It is a unit that controls the typical 24 VAC heating/cooling system. But now, how do I hook it up to the A/C? Simple! Build a controller box that interfaces between the A/C and the thermostat. I wanted to do this without making any modifications to the A/C. Refer to Figure 2 for a view of the finished controller.



■ **FIGURE 2.** End view of the finished controller.

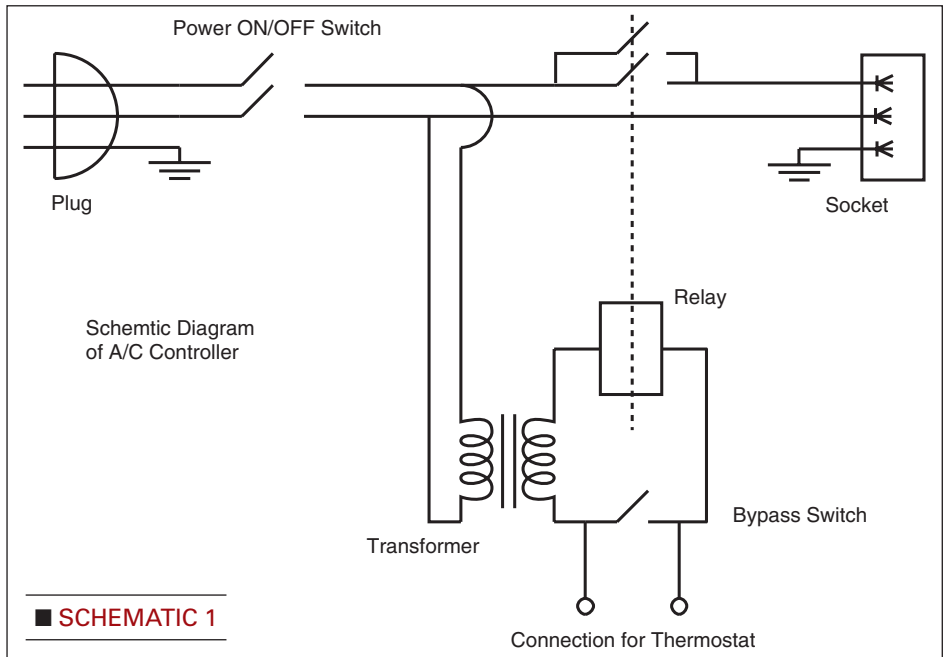


■ FIGURE 3. End view showing the power switch and the power cord.

I obtained the following materials:

- An aluminum project box – 5 x 4 x 3 inches.
- A relay whose A/C contacts were rated at or about 10 amps and with a coil voltage of 24 VAC.
- A sub-miniature single pole single throw toggle switch.
- A power on/off switch rated at 125 VAC and 10A.
- A transformer for converting line voltage to 24 VAC.
- A six-foot A/C extension cord.
- An AC receptacle.
- Miscellaneous hardware including wire, terminal strips, nuts and bolts, and crimp connectors.

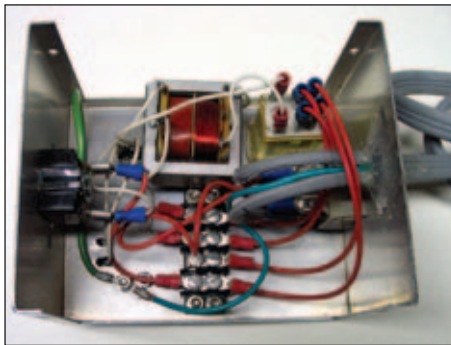
I am not detailing the parts I used, as most had been recycled. For example, the power on/off switch was taken from an old computer



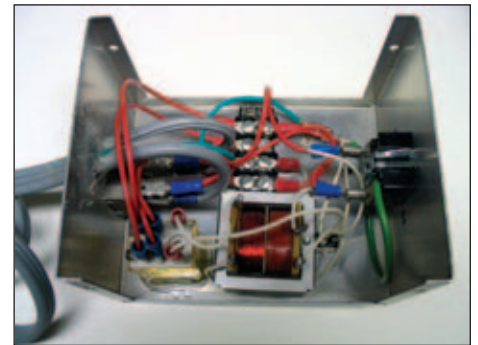
I had disassembled. The 24 VAC transformer was from an old oil-burner

controller. The relay was one of many I had in my spare parts bin, and so on.

■ FIGURE 4. Interior view of the controller showing the wiring.



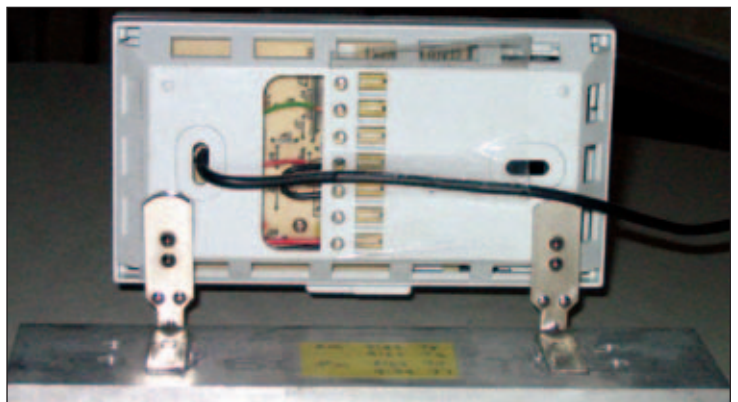
■ FIGURE 5. Opposing interior view of the controller showing the wiring.

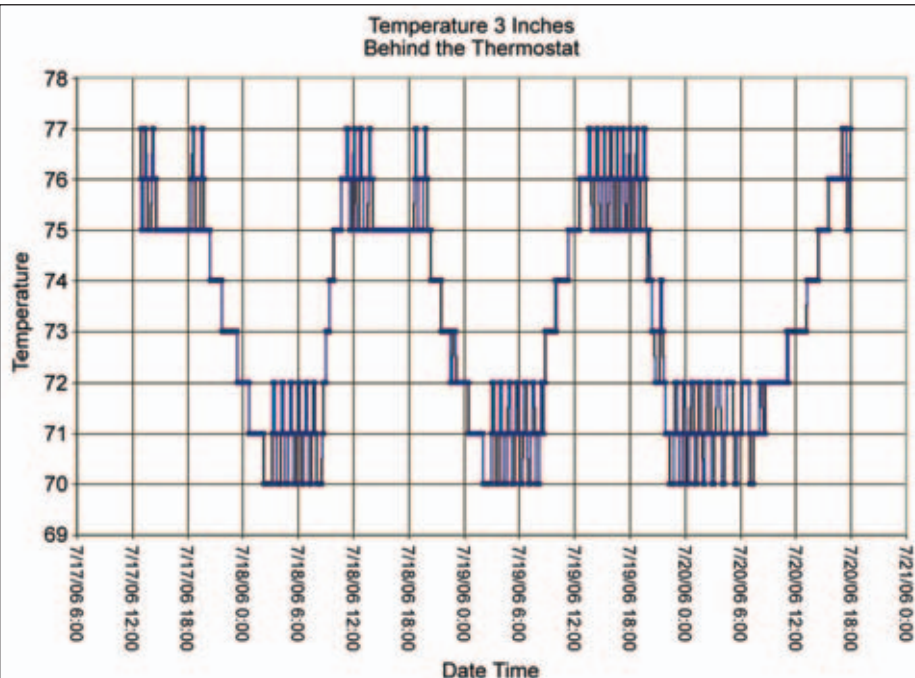


■ FIGURE 6. View of the controller in use.



■ FIGURE 7. Back view of the thermostat showing how it was mounted to an aluminum bar for stability.





Before I chose a relay, I monitored the run current of my A/C. I wanted to make sure that the contacts could handle the load. The A/C draws 4.3 amperes when both the compressor is running and the fan is set on high speed. My setup did not allow me to measure the startup current, but I didn't think it would be excessive. The relay I used has

two sets of contacts rated at 5 amperes each. To handle the startup current, I wired them in parallel. The controller has now performed its intended function for two summers. So, I know it is reliable.

The circuitry is straightforward. (Refer to Schematic 1.) The low voltage temperature sensing system controls the line voltage AC through a

■ **FIGURE 8.** The upper and lower target temperatures of 76°F and 71°F were achieved at the thermostat.

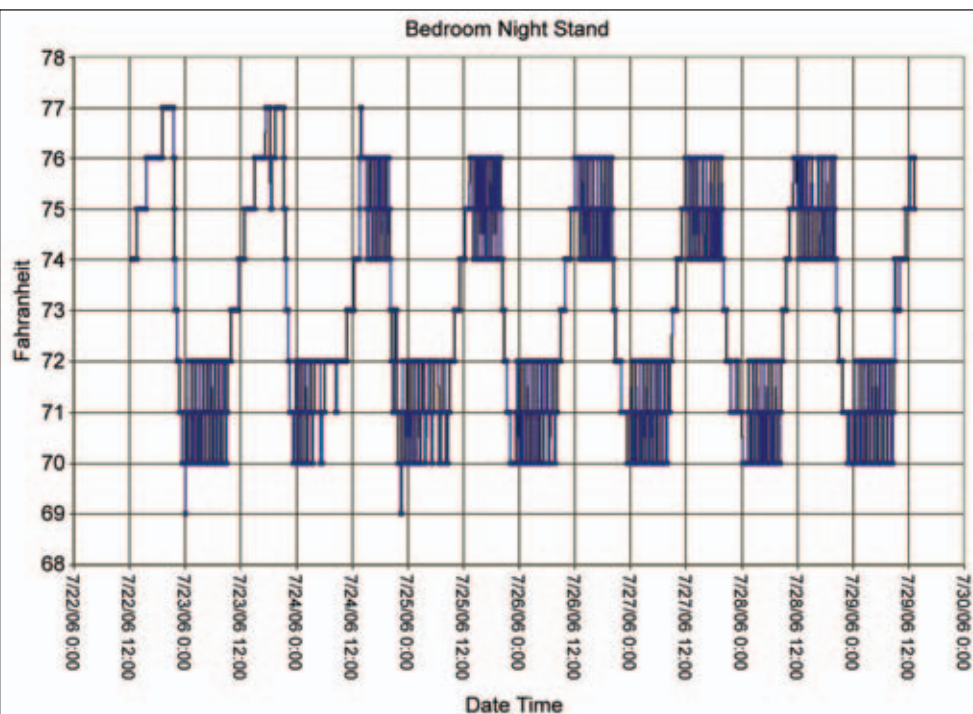
relay. All line voltage connections were made using crimp terminals. The low voltage wires were soldered. Terminal strips were used where needed to secure all the connections.

An option I wanted was to turn on the A/C without having to adjust the thermostat. I did this by adding a subminiature toggle switch. All it does is parallel the input from the thermostat. When I toggle the switch to ON, it applies 24 VAC to the relay by shorting the connection to the thermostat and the A/C comes on. At least the fan comes on if the inside temperature is higher than the outside temperature. After a few moments, the compressor comes on.

I shortened the six-foot A/C extension cord I had acquired by cutting off about a foot from the socket end. In the project box, I cut an oval hole larger than the wide part of the A/C extension cord. To prevent chafing of the cord, I got a large grommet, cut it to fit the opening, and glued it in place. The leads were trimmed to fit and the cord was fixed in place in the oval opening with a liberal amount of a high-strength adhesive. It is unlikely that the cord will pull out. I also made a hole which would accommodate a power ON/OFF switch; in this case, I had used a recycled power switch from a computer. Refer to Figure 3 for a view of the switch.

At the other end, I made a hole into which I fit a single 120V socket. On the top of the project box, I drilled two holes to accommodate the 24 VAC control lines. I affixed a two-terminal terminal block adjacent to them so I would have a connection point for the signal wire between the thermostat and the controller box. Next to it, I drilled a hole which would accommodate my subminiature toggle switch. On the inside, I laid out a four terminal

■ **FIGURE 9.** The upper and lower target temperatures were closely met at my bedside.



Beat the Heat With This External A/C Controller

strip for the high voltage connections. I then laid out the transformer and the relay to fit. The green ground wires were attached to the inside of the project box. The only connections that were soldered were the toggle switch contacts and the connections to the transformer. All other connections were made using crimp terminals. Refer to Figures 4 and 5 for views of the wiring.

After I had rechecked all of the wiring, I put the lid on. I plugged the A/C cord into the socket on the controller box, I set the power switch to OFF. I set the fan control to HI FAN and the TEMP control to 6. I plugged the cord into a wall socket. I then turned on the power switch; so far, so good. I then flipped the bypass toggle switch to ON. And success! The A/C came on and ran normally. Refer to Figure 6 for the installed view. The thermostat can be programmed for days of the week and the weekend. It has the option for several temperature settings for the day. I settled on the following:

- 8:30 AM 74°F
- 9:00 AM 76°F
- 8:00 PM 73°F
- 9:30 PM 71°F

Rather than mounting the thermostat on the wall, I mounted it on a heavy aluminum plate that serves as a base. I placed the thermostat about

five feet away from the A/C unit and out of the air flow. Refer to Figure 7 for a view of the thermostat. The bedroom is large being about 30' x 15'! The bed is located at least another 10 feet away from the thermostat. I used a datalogging thermometer to measure the temperature at two locations: one two inches behind the thermostat and the other on the nightstand next to my bed. The results exceeded my

wildest expectations. Refer to Figures 8 and 9 which show the temperatures at the thermostat and at my bedside.

As I had mentioned earlier, details were not provided for the components of the controller. Part of the reason is that such components can be hard to find to exactly duplicate the design. And part of the reason is that rooms and air conditioners can vary widely. You should make adjustments to fit your situation. **NV**

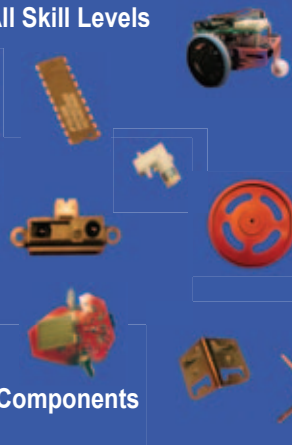
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PARTS LIST

ITEM

- ☐ An aluminum project box — 6" x 4" x 4".
- ☐ A relay whose A/C contacts were rated at or about 10 amps, with a coil voltage of 24 VAC.
- ☐ A sub-miniature single pole single throw toggle switch.
- ☐ A power on/off switch rated at 125 VAC and 10A.
- ☐ A transformer for converting line voltage to 24 VAC.
- ☐ A four foot A/C extension cord.
- ☐ An AC receptacle.
- ☐ Misc. hardware including wire, terminal strips, nuts and bolts, and crimp connectors.

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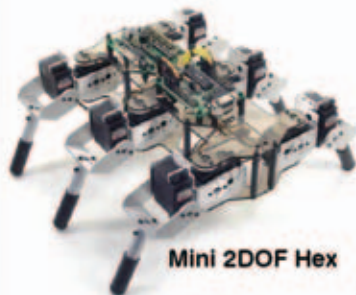
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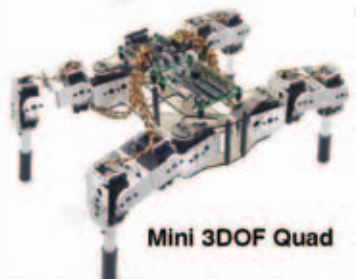
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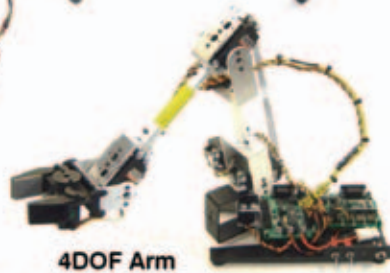
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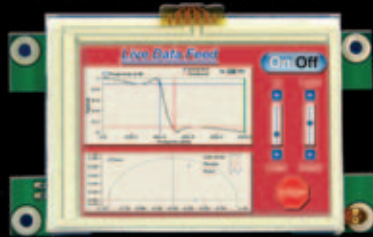
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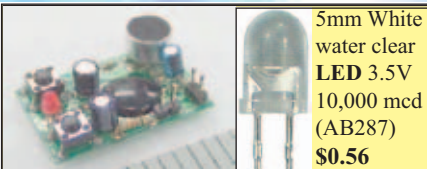
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Continued from Page 6

IN MEMORIAM *continued*

as best he could, got his left earlobe pierced, and often wore long, weighty earrings with Native American themes. He looked like an aging biker, which was just fine with me.

During that time, he began to write the Q&A for *Nuts & Volts*, gaining a devoted readership over the years. Some of you know his history better than I do, having followed his byline in various publications for thirty-some years.

One of my friends says he was a "Dickensian character." That is, he was indeed "a character," a bit eccentric and quirky, but always true to himself. His Native American grandfather was his mentor, teaching him to speak softly, walk silently, and never hit anybody weaker than himself unless to save his own or others' life. Physically, he was compactly built, but amazingly strong until the final months. He was sufficiently confident of his masculinity to treat a woman well. He could build or fix anything, although he rarely completely finished the fixes before moving on to the next project. He left his office an unholy mess, cluttered with arcane electronic equipment like "Dr. Weirido's Strange Science Lab."

In his last years, he also became a "foodie," aiding me in my job as restaurant critic for the *San Diego Reader*, and travelling with me on culinary vacations to Trinidad, Thailand, and Hong Kong. He gladly shared his lifelong interest in Japanese cuisine. I'd eaten plenty of sushi before we met, but only learned the "inside story" by helping him make

it at home — fanning the rice, carefully stirring in seasonings taste by taste, experimenting with ingredients. TJ was invaluable — not only another welcome mouth to feed, but a researcher, editor, and superb palate who shared my enthusiasm and helped in my labor.

He was brilliant, sweet, kind, and funny. He was truly a man. I can wish each of you no greater boon than a partnership like ours.

Joan

I believe I first encountered the writing of TJ Byers around 20 years ago in the pages of *Modern Electronics* magazine. Over the years, we exchanged occasional notes via email and

talked about meeting in person some day. I will miss TJ's great enthusiasm for experimenting and teaching others about circuits and what they can do.

Jan Axelson
author of *USB Complete*

I just learned from the on-line edition the sad news that TJ Byers has passed away. His knowledge of electronics was awesome. He published answers to one or two of my questions, and answered others by email; we also corresponded about some of his answers. I will miss him.

Bill Stiles
Hillsboro, MO
Continued on Page 95

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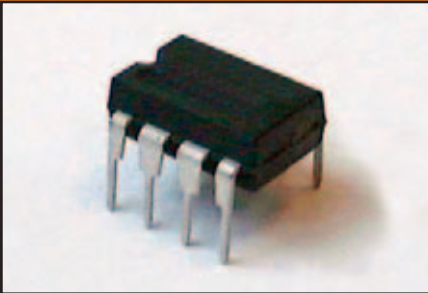


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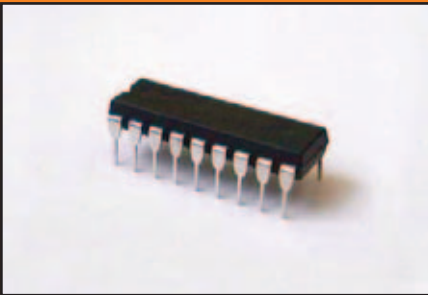
PART 3

by Ron Hackett

The PICAXE-08M Chip



The PICAXE-18X Chip



The PICAXE-28X Chip



The PICAXE-40X Chip



Last month, we interfaced the 18X with a Hitachi HD44780-based LCD display. **Now we are ready to add a 12- or 16-key matrix keyboard and a piezo beeper to complete our I/O terminal.** For those projects that do not require user input (i.e., they only need the LCD for program output), we will also discuss a simplified version of our terminal program that will provide just the “serialized” LCD for output, as we conclude this series.

Matrix Keyboards

Let’s begin by taking a look at matrix keyboards; 12-keys (3X4 matrix) and 16-keys (4X4 matrix) are the two most commonly-available sizes. We will be using a Velleman 4X4 matrix keyboard (BGMicro part #SWT1067; also available on eBay) in our discussions, but you can just as easily use a 3X4, if you prefer. In

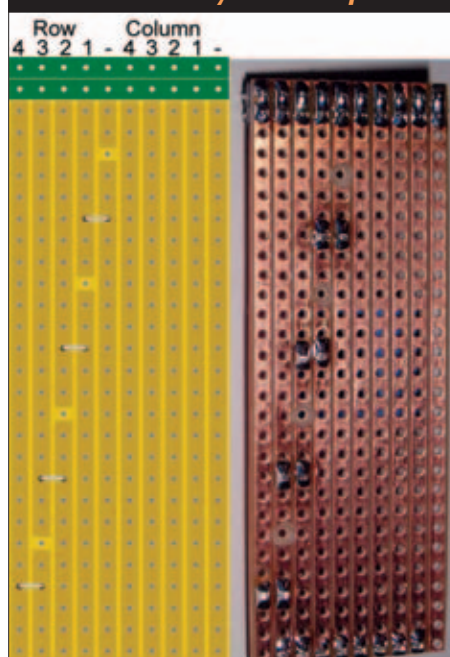
fact, because of the way the software functions, you will most likely not have to make any changes to accommodate the smaller keyboard.

When a key is pressed on a matrix keyboard, a connection is made between the column pin and the row pin which correspond to the position of the switch in the matrix. Later, we will see how a microcontroller can be used to determine which key has been pressed, but first we need to focus on the mechanics of interfacing the keyboard to a microcontroller. Our discussion will be limited to the 4X4 matrix, but 3X4 matrices function in exactly the same way — just with one less column pin.

A few matrix keyboards come with cables already attached, but most simply have a row of seven or eight holes into which you can solder a header for connection to your project. The options for interfacing keyboards are similar to those discussed last month when we were interfacing LCDs. Essentially, you can solder a male header to the keyboard and either connect it directly to your breadboard or use a short 16-pin ribbon cable with 2X8 IDC connectors on each end to connect the keyboard header to a male header plugged into the breadboard.

Some keyboards — such as the one

FIGURE 1. Keyboard Adapter.



from Velleman — are straightforward in that their pinout matches the physical arrangement of the keys (i.e., pin 1 = column 1, pin 2 = column 2, pin 3 = column 3, pin 4 = column 4, pin 5 = row 1, pin 6 = row 2, pin 7 = row 3, and pin 8 = row 4). In other keyboards, there seems to be absolutely no relationship between the pinout and the physical arrangement of the keys. In any case, it's helpful to have a diagram of the keyboard; if not, you will need a continuity tester and some patience to map out the correspondence for yourself. Many keyboards available online have links to their data sheets; you can use this information to help you decide which keyboard best meets your needs before actually purchasing one.

The standard method of interfacing a matrix keyboard is to connect the “row” pins to inputs on the microcontroller and the “column” pins to outputs. (The reason for this arrangement will become clear when we discuss the keyboard software below.) If you look at the pinout for the PICAXE-18X, you will notice that one side of the chip (pins 10-18) consists of four inputs and four outputs separated by the +5 volt power connection. If it weren't for the power connection in the middle, it would be a simple matter to insert a male header along this side of the 18X and directly connect the keyboard. A second minor inconvenience is that the connector on the chosen keyboard is located at the bottom; it would be much more convenient if it were at the top.

To correct both of these issues, you can construct a small adapter from a piece of stripboard. If you are not familiar with stripboards, check out www.kpsec.freeuk.com/stripbd.htm and look at the Sources sidebar. The wiring diagram for the adapter and a photo of the copper side of the completed stripboard is presented in Figure 1. (Both are seen from the bottom, so the pinout is reversed.) Figure 2 shows the top of the completed adapter, along with the keyboard. In this photo, the pinout is in the normal (non-reversed) order.

Essentially, the stripboard adapter attaches to the back of the keyboard

and adds a two-row by 10-pin male header to the top of the keyboard. On this connector, the four column pins and four row pins are separated by an unused pin to allow for the +5 volt power connection on the PICAXE-18X. As a result, the keyboard can be connected to the 18X by using a short piece of 20-pin ribbon cable with an IDC connector on each end. On the breadboard end, the connector can be plugged into a 10-pin male header. Each adjacent pair of pins (1 and 2, 3 and 4, etc.) is redundant, so it does not matter which 10-pin row of the connector is inserted into the header. The resulting breadboard setup for the I/O terminal is shown in Figure 3.

The stripboard adapter is not necessary to connect the keyboard to our project. You could just insert the keyboard directly into the breadboard and use eight jumper wires to connect it to the 18X. However, a larger breadboard would probably be required to do it that way. Whichever approach you choose, it's time to connect the keyboard to the 18X.

If you are using the keyboard adapter, it is important to note that pins 1 and 2 of the connector are not used; be sure to connect the keyboard as specified in the terminal schematic shown in Figure 4. The fact that outputs 4 through 7 (pins 10-13) of the 18X are connected to both the LCD and the keyboard may seem strange at first, but we will soon see how the software avoids having a problem with this arrangement.

As you can see in Figures 3 and 4, we have also added a piezo “beeper” on output 1 (pin 7) of the 18X. We will use it for simple audio feedback whenever the software has received a key-press. This can be very helpful during development, but if you find it to be annoying, you can omit the beeper or disconnect it at any time without needing to change the software at all.

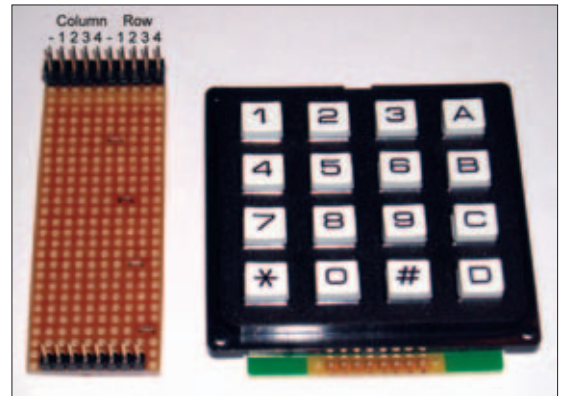


FIGURE 2. Adapter and Keyboard.

Testing the PICAXE-18X I/O Terminal

At this point, we are ready to take a look at the software that we will use to test and implement our I/O terminal. We will be working with five different programs: three for the PICAXE-18X and two for a PICAXE-08M, which we will use as a simple target project to test the functioning of our terminal. (We will discuss the 08M a little later in the article.) Since the five programs would be too lengthy to type into the Program Editor, you can download a Zip file containing them from the *Nuts & Volts* website (www.nutsvolts.com).

Once you have downloaded and unzipped the programs, double-clicking on any one of them will open it in the PICAXE Programming Editor. Before using any of these programs, make sure you have the latest version of the Programming Editor (v5.0.7)

FIGURE 3. Terminal Breadboard.



Getting Started With PICAXE Microcontrollers

functions, we first need to construct a simple PICAXE-08M circuit (either in an empty space on the Terminal breadboard or on a second small breadboard). Figure 5 presents the schematic for this circuit, which is simply the PICAXE-08M programming circuit. Because we are transmitting data back to the PC on the programming connector's Serial Out line (pin 7), no additional connections to the 08M are necessary.

If you have a second serial port available on your PC, you can use two serial connections at the same time without having to move your three-pin programming adapter back and forth between the 08M circuit and the 18X circuit. Simply construct a second three-pin adapter, connect it between the 08M circuit of Figure 5 and your PC, and you are ready to download Sertxd.bas to the PICAXE-08M. If you only have one available serial port, you will have to "cable swap" whenever you switch between downloading the 08M software and the 18X software, or vice versa.

When you have constructed the circuit of Figure 5 and have Sertxd.bas open in the Programming Editor, make sure you have the Options set for the PICAXE-08M and the correct serial port. Also, in the Editor's View menu, select Options and then select the Editor tab. In the Serial Terminal section, check the "Automatically open Serial Terminal after download" option, so you will be able to view the serial output from the PICAXE-08M. Download Sertxd.bas to the 08M; you should see the words "One" through "Ten" repetitively displayed in the Terminal Window. If you get an error message, recheck the Option settings and try again.

Once Sertxd.bas is working properly on the 08M, we're ready to modify it to output the data from output 4 (pin 3) on the 08M to the one remaining input on the 18X (input 2 on pin 1). The only changes we need to make in the Sertxd program are to replace the first Sertxd command with "Serout 4, N2400 (outchar)" (which transmits our serial data on output 4 at 2400 baud) and to remove the second Sertxd command [Sertxd (cr,lf)]. You may want to save the new file as Serout.bas, so you

have both of them to experiment with.

In case you were wondering, "cr" stands for "carriage return" and "lf" stands for "line feed;" both definitions are built into PICAXE Basic, but I don't think they are documented — I stumbled across them accidentally! If the Serout syntax is confusing, read through the documentation in Part 2 of the PICAXE manual; it should help clarify things.

To connect the 08M and the 18X, just disconnect the power from both circuits and add a jumper wire from output 4 (pin 3) on the 08M to input 2 (pin 1) on the 18X. If your two circuits are on separate breadboards, it is also necessary to connect the grounds of both breadboards with a second jumper wire.

On the 18X, the SerinLCD.bas program will receive the 08M's serial transmission and display it on the LCD. In effect, a PICAXE-18X with SerinLCD.bas loaded into its program memory converts any HD44780 LCD into a serial LCD for use in your projects. In addition, you can easily modify the program to include additional features you find useful. You could also construct a complete circuit on a stripboard the same size as the LCD and attach it to the LCD board to make your own serial LCD module.

Of course, the characters displayed on the LCD by SerinLCD.bas are specific to the keyboard being used, so they may not be appropriate for your keyboard. To correct this, locate the branch statement in SerinLCD.bas and

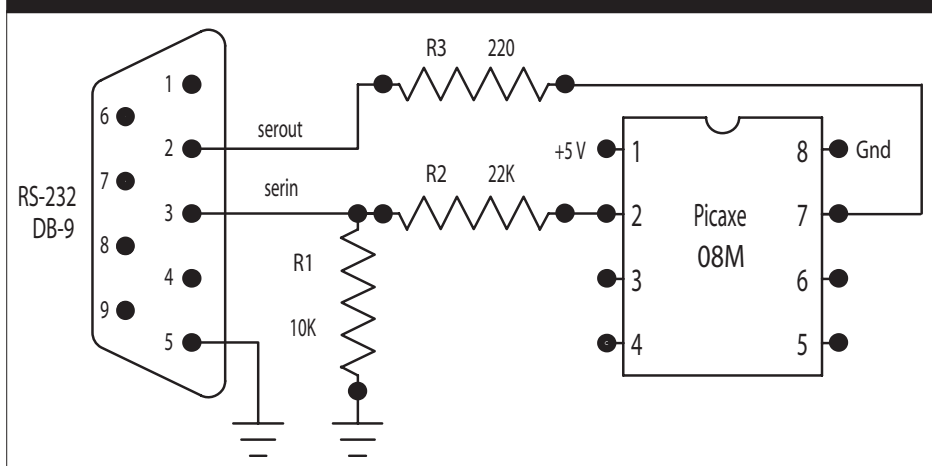
replace the data characters with ones that match your keyboard.

Now that we have the two circuits connected, it's time to download the software and test the system. First, set up the options in the Programming Editor for the 18X circuit; make sure you have set the correct serial port on the PC. Download SerinLCD.bas to the 18X, change the Option settings (and your programming cable if you are using only one), and download Serout.bas to the 08M. After a brief pause, the words "One" through "Ten" should be sequentially displayed on the LCD, along with an annoying beep for each word. If not, you will need to troubleshoot the system, which is getting a little complex by now!

Implementing the Complete I/O Terminal

At this point, we are ready to begin working on our stand-alone data terminal. First, we need to power-down both circuits again and add one more jumper wire connecting output 0 (pin 6) on the 18X to input 2 (pin 5) on the 08M. This connection will provide for serial output from the Terminal to the Target. It's a good idea to include a 1K resistor in series in this connection; pin 5 on the 08M is a bi-directional I/O pin, so it's possible for it to be accidentally set to be an output pin. The direct connection of two output pins (with no current-limiting resistor) can result in a high-level out-

FIGURE 5. PICAXE-08M "Sertxd.bas" Schematic.



Getting Started With PICAXE Microcontrollers

SOURCES

PICAXE-18X

www.hvwtech.com
www.phanderson.com
www.picaxe.co.uk
www.world-educational-services.net

PICAXE-08M

www.hvwtech.com
www.JRHackett.net
www.phanderson.com
www.picaxe.co.uk
www.world-educational-services.net

Character LCD

www.allelectronics.com
www.ebay.com
www.goldmine-elec.com
www.mouser.com

Matrix Keypad

www.acroname.com
www.BGMicro.com
www.ebay.com
www.hvwtech.com

Stripboard

www.futurlec.com

put and a low-level output creating a direct short in the connection, which can damage one or both PICAXEs.

Power-up again, and download TestTerm.bas to the 08M. This simple program receives a single key-press from the Terminal and sends back an appropriate six-character response. There are ways to write serial communications software that allow for variable-length responses, but they all require testing each received byte for an end-of-line character (usually ACSII character 13, which is the "cr" character). This complicates the software and slows things down considerably, so we are using the fast and easy approach of controlling the length of the transmission.

Next, download Terminal.bas to the 18X. The terminal program is more complicated; essentially, it performs the following tasks:

- Wait for a key-press on the keyboard.

- Echo the key-press on the LCD.
- Serially transmit the key-press to the target project.
- Wait for the six-character serial response from target project.
- Display the target's response on the LCD.

We have already seen most of the code in Terminal.bas; the major new portion is the "scanloop" routine in the main program. The most important part of the code to understand is the portion that receives and echoes the six-character response from the target, so a little explanation is in order. Similar to BASIC Stamp processors, PICAXEs have 14 variables available to the user (designated as b0, b1, ... b13). We are using the last six of these variables to receive the response [in the line "serin 2, N2400, b8, b9, b10, b11, b12, b13],

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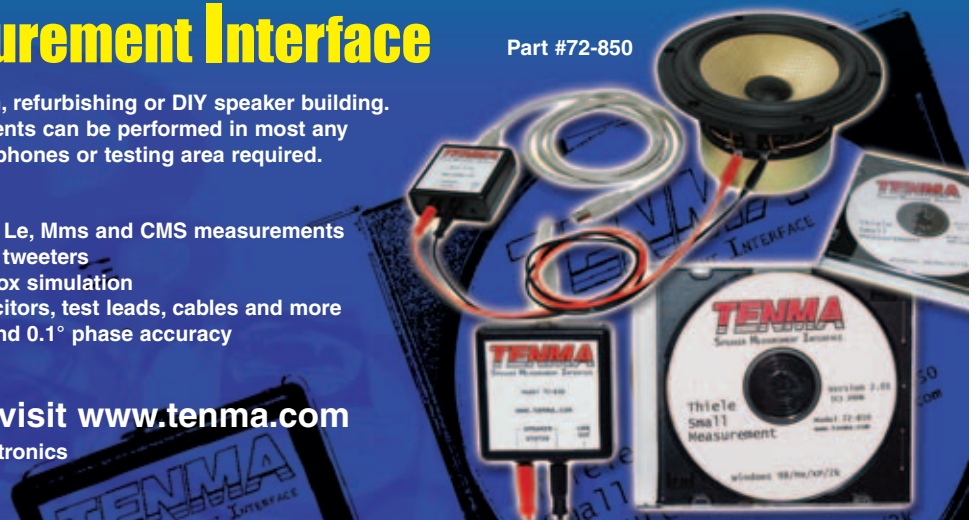
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Having received the six characters, we could now write six short routines that sequentially assign each character to our "char" variable and write it to the LCD, but the for-next loop that follows the serin command is a quicker (and more elegant) way to do it. To understand how this code works, you need to know that the 14 variables are stored sequentially in PICAXE memory locations 50 through 63. (The author thanks "Hippy" from the PICAXE Forum for providing these exact memory locations; if you haven't yet browsed the postings on the PICAXE Forum [www.rev-ed.co.uk/picaxe/forum], give it a try — it can provide a tremendous amount of useful PICAXE information, and its members usually can answer just about any question you may have.) Once you know the values for the memory locations, the for-next loop is straightforward — we are just sequentially "peeking" each character

and sending it to the LCD.

Okay, the moment of truth has arrived! Both programs are downloaded into their respective PICAXEs, and a key-press at the terminal should generate an appropriate message on the LCD display. (If not, you have a little more troubleshooting to do!)

Conclusion

While the content of the target's responses may seem a little trivial, the interaction of the programs definitely is not. With minor changes, the Terminal program can function as a stand-alone I/O terminal for use in the development, testing, and debugging of all your future microcontroller-based projects, PICAXE-based and otherwise. Admittedly, our terminal program is somewhat basic at this point, but it can be easily modified and/or expanded to suit the project at hand. If you use it as much as I have, you may even want to

convert it to a stripboard circuit and mount it in a plastic enclosure to make a very professional-looking project.

The other major goal of this series has been to provide an introduction to PICAXE programming. To this end, I hope the series has whet your appetite for working with PICAXEs. We have barely scratched the surface of PICAXE capabilities. In addition to the standard Basic commands, PICAXE Basic includes an impressive array of special-purpose I/O commands. Browse through the three parts of the PICAXE manual and you will see what I mean. Also, be sure to spend some time on the PICAXE Forum — you will be amazed at the quantity and scope of the helpful information available there. **NV**

AUTHOR BIO

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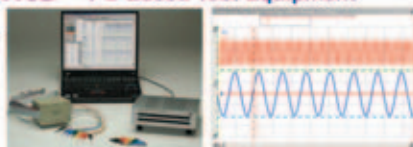
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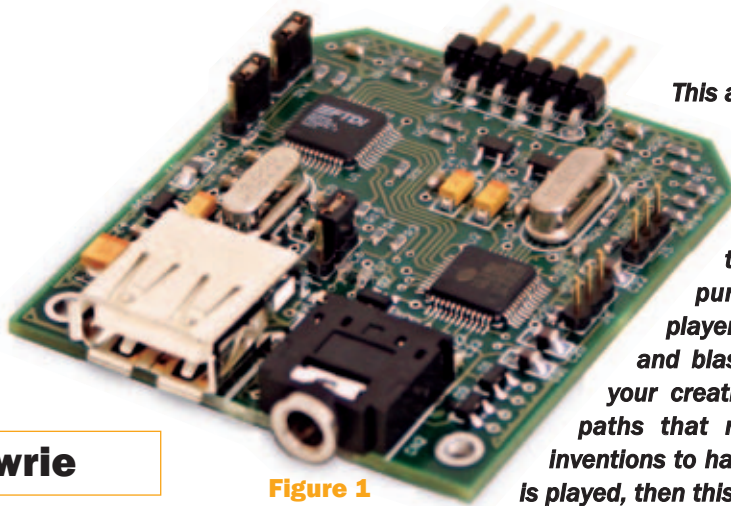


Figure 1

This article is all about utilizing audio files stored on a USB Flash drive in unusual applications. If all you want to do is listen to your favorite tunes, then that's easy enough. Just purchase a garden-variety MP3 player, strap on a pair of headphones, and blast away. If, on the other hand, your creative adventures take you down paths that require your latest electronic inventions to have control over which audio file is played, then this article is for you!

Grab a low-cost microcontroller, load your USB Flash drive with audio files, and fire up your imagination! This article will show how to select and play MP3 and other popular digital-format audio files directly from a USB Flash drive.

Data Access

The first challenge in playing an audio file is retrieving the file in question from the USB Flash drive. Since talking to a USB Flash drive is a "USB Host" type activity, data stored on it was once only accessible via a PC. What has been needed is a bridge of sorts between the microcontroller and the USB Flash drive that doesn't involve the bulk of a PC. Wouldn't it be nice if

this could be done with a single, easy-to-use chip?

The good news is that this call has since been answered. There is a new IC available from FTDI called the Vinculum (www.vinculum.com) that provides USB Host services and is unbelievably easy to use. Since the Vinculum is programmable, it is capable of much more than just interfacing a small microcontroller to a USB Flash drive for audio playback. This is, however, the application we will be discussing here.

Vinculum and VLSI VS1003

To interface to the Vinculum IC, you simply connect a USB Flash drive to one side using a couple of resistors and capacitors, and your microcontroller's TX/RX/CTS/RTS serial interface to the other. That's it. The microcontroller activates its UART at 9600

baud and sends over serial commands like "DIR MYFILE.TXT" to see if the file is available and "RD MYFILE.TXT" to open it and retrieve the data in the file back into the microcontroller on the RX line. This is great if all you want to do is to read and write data files. What if you would like to play music or other audio files?

Not only is the Vinculum programmable, it also has two interface ports available so that it can connect a microcontroller to both a USB Flash drive and an MP3 processor chip like the VLSI VS1003. Communicating with the VS1003 takes a bit more work, so the folks over at FTDI (www.ftdichip.com) developed a new module (Figure 1) that combines the Vinculum, VS1003, and firmware called the VMUSIC1.

With the VMUSIC1 module, simply writing the serial command "VPF MYSONG.MP3" will start the playback of an associated song on the USB Flash drive.

Application

So, now the stage is set. Using

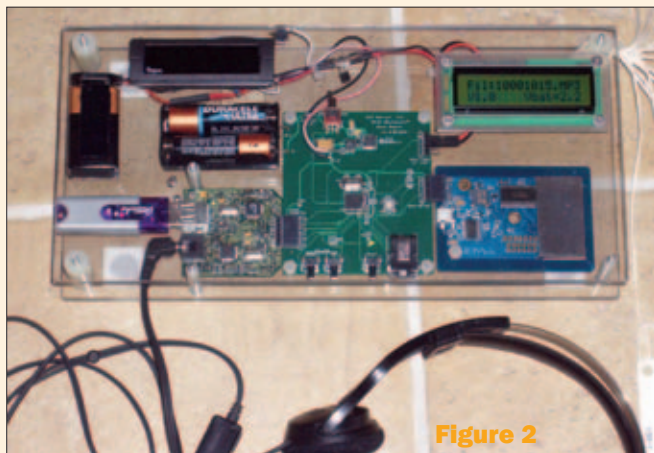


Figure 2

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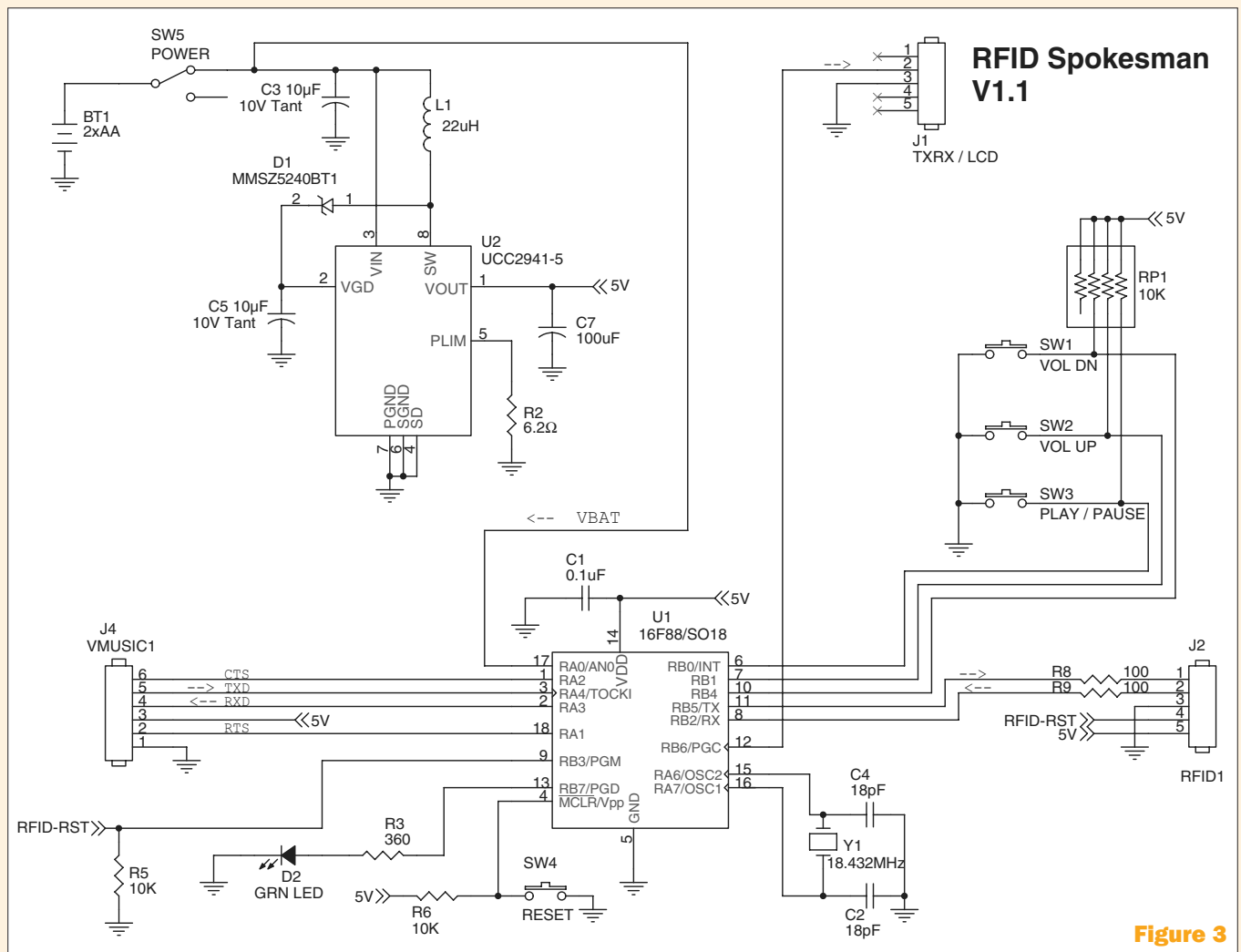


Figure 3

the VMUSIC module, we can select and play an audio file from a USB Flash drive using only our small micro. All we have to do now is decide how to use it. We could utilize a microcontroller to read a numeric value from a keypad that corresponds to an audio file and play that file; or we could use the digital inputs of a micro to read a series of switches, each switch initiating the playback of a different audio file; or, well, you get the idea ...

I decided to select the audio file to be played by having a microcontroller read four bytes from an RFID tag, combine those four bytes to a 32-bit number, convert that number to hexadecimal ASCII string, append ".MP3" to the string, and use that as the file name. Using this application, people participating in a scavenger hunt could obtain audio hints by

holding the RFID/VMUSIC combination up to tags mounted at strategic locations. The audio files would then provide clues as to where to look next.

This system could also be used in museums or art galleries to describe a work of art. The patron would simply hold the player up to an RFID tag that is hidden behind a plaque to hear all available information about a given piece. With a little extra effort, the curator could even utilize an artist's voice in the audio playback.

Prototype

Figure 2 displays a snapshot of the prototype platform. Additional pictures, as well as a PDF of the schematic, are available for download from www.dlpdesign.com/pub.shtml. Since I wanted

the system to be small and lightweight, I decided to go with only two AA batteries as the power source. The RFID reader, VMUSIC1 module, and microcontroller all needed five volt power, so the first order of business was to incorporate a DC-DC converter. The TI UCC2941-5 was chosen due to its ease of use and availability. Otherwise, there are probably hundreds of other converters that would work. The DC-DC converter circuit is in the upper left quadrant of the schematic (Figure 3).

The RFID tags used here have two kinds of memory: a permanent serial number that cannot be changed, and 256 bytes of "user memory" arranged in groups of four bytes or "blocks." I wrote a different four-byte block of data to each of the 16 tags that corresponded to 16 different audio

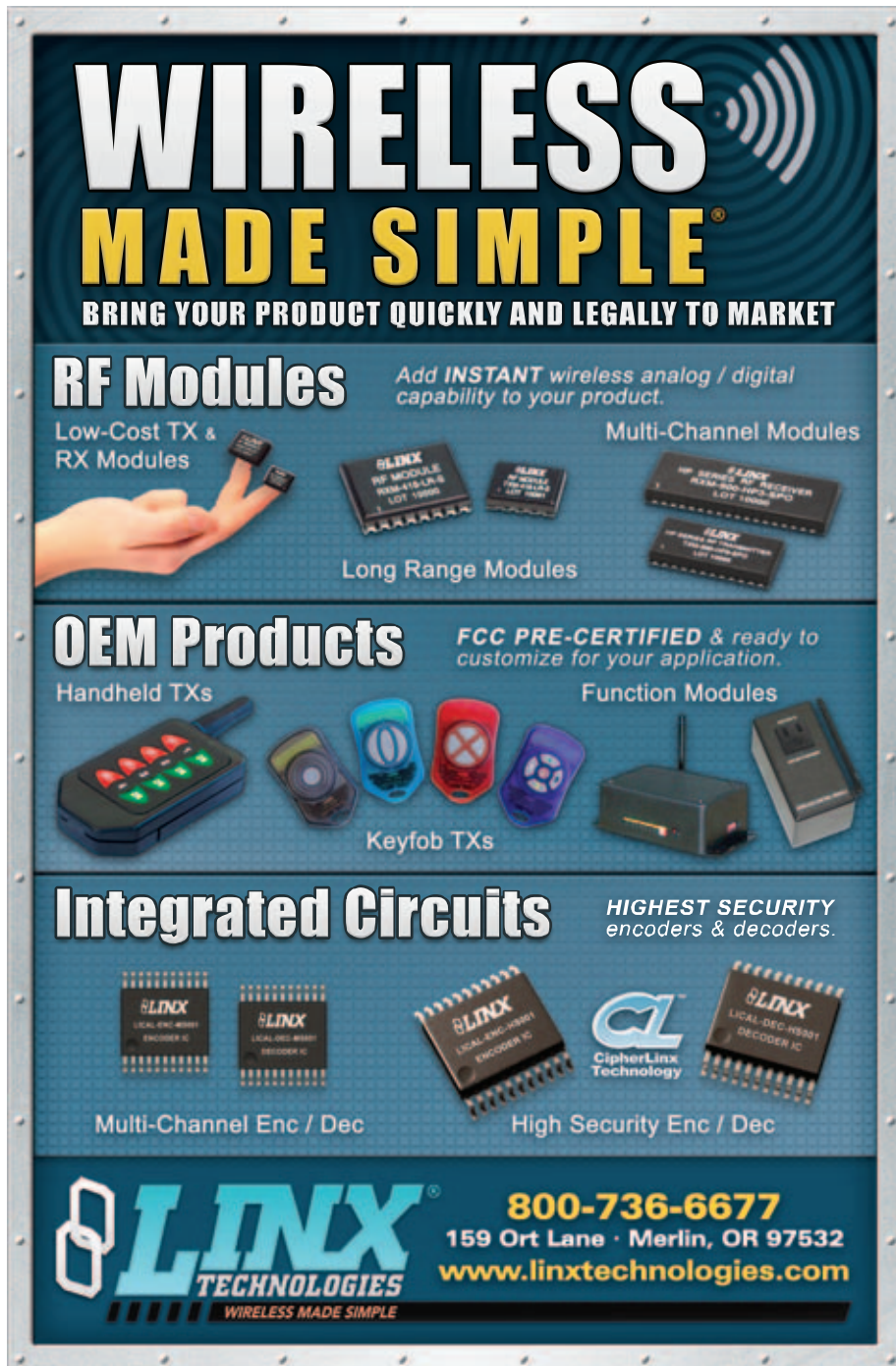


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files. Before loading the USB Flash drive with the audio files, each file was renamed from the original name of the song to the xxxxxxxx.MP3 ASCII string as described earlier.

Since both interrupts and a data rate of 115,200 baud were required, it was necessary to use the micro's only UART for communication with the DLP-RFID1 RFID reader. This meant that serial communication with the VMUSIC1 module would have to be done via software (not via a UART), which was not a problem since we only needed a rate of 9600 baud and no interrupts. In fact, if this system did not use the RFID reader with its high data rate requirement, we could have eliminated the crystal from the design altogether and used the microcontroller's internal 8 MHz oscillator instead.

I added a serial LCD display to be able to see the name of the audio file being played and an LED that was turned on to indicate when the micro was out of Sleep Mode, requesting an RFID tag to trigger a song selection. In fact, all that is really needed to make the VMUSIC1 play music is four pins from a small microcontroller and a five-volt power supply.

Conclusion

If you want to be able to say "I designed my own MP3 player" then yes, this platform could be used as the starting point. After all, all that's needed to implement a player is some form of storage for the audio files, a power source, an (optional) LCD display, and a few buttons for song selection. However, with a little imagination, the VMUSIC1 module opens up a world of possibilities from interactive talking robots to adding voice or music to ANYTHING that has a microcontroller.

So, put on your thinking cap, grab your microphone, and start creating audio files. The VMUSIC1 module will handle the hard part of audio playback for you. **NV**

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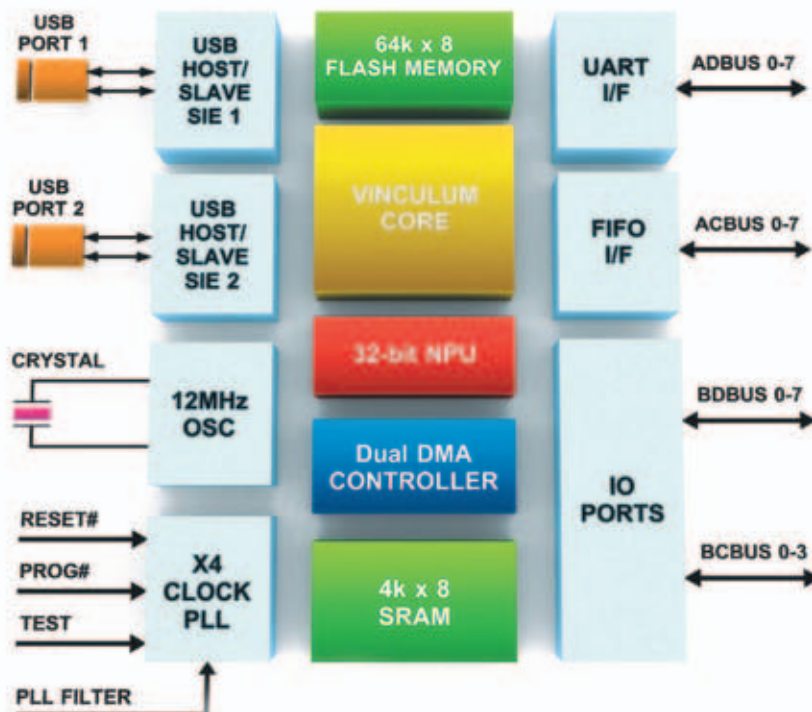
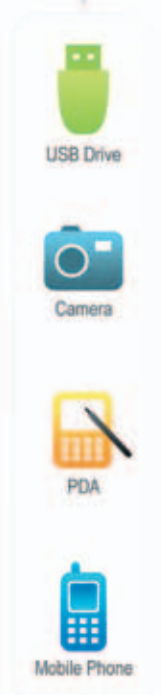
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by David Geer

Setting Up DUAL, FLAT PANEL MONITORS Under Windows XP

Here's an easy way to set up a really cool and useful computer display configuration that will make friends think you're a super-geek!

Why Set Up Dual, Flat Panel Monitors?

Well, you get at least five benefits. One, you have twice the desktop space because your mouse, applications, documents, and viewing area go across both screens; in other words, the two screens form one display.

Two, you can multitask in that you can have one document or program open in one window and one open in another, both to full screen if you like. Three, you can save space by hanging

or mounting these monitors on the wall instead of having them on your desk (mounting instructions not included).

Four, if something goes wrong with one display, you still have the other. Five, you can set the screen resolution and color settings for each display independent of the other if you like.

And, six (yes, six), though this type of setup takes some getting used to, you will reap enormous benefits in productivity and personal enjoyment once you adjust.

Parts — Hardware, Software

You will need a computer that has two monitor ports inside, PCI or AGP ports; these port types will determine

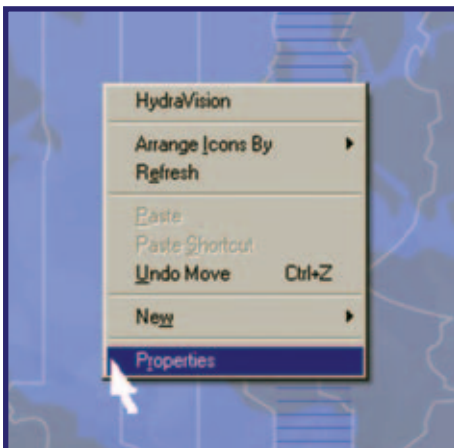
the port types you need for the video cards you will need. The computer should be running the Windows XP operating system.

You will need two flat panel display monitors of equal size. These should preferably be of the same make and model, compatible in appearance with your computer, and of viewable screen dimensions great enough that together they will give you a much broader viewing area than your current monitor.

You will need two video cards, one for each flat panel monitor. Both cards must support the type of flat panel monitors you have; you will need to check with the manufacturer. I would ask the manufacturers of both the monitors and the cards. The vast majority of recent video card lines will have a model that will work.

You will need to use display adapters (AGP or PCI, same thing as video cards above), as these support this application. While most adapters that meet the above requirements will work for display number one, display number two's adapter must have independent driver support.

This is a screen shot of the menu you will see when you right click on the desktop and are about to left click on Properties.



Or, Pick These Cards — For Laptops With the Dualview Feature

XP supports at least the following video/graphics cards/adapters, some of which appear with the vendor website.

These cards work with laptops that come with XP and the Dualview feature, in which you can share the desktop between the laptop display and a separate display.

- www.tridentmicro.com — Trident XP and 3D
- www.s3graphics.com — S3 Savage MX

A number of manufacturers offer mounts for multiple monitors as the dual monitor setup actually affords up to 10 monitors once installed and recognized by your computer. Check out vendors like Ergo In Demand, Ergotron, and the Monitor Outlet.

You will need the cabling for each display to be compatible both with the monitor's port type and the video card's port type. Make sure they are all the same.

You will need a basic computer tool kit or a Phillips screwdriver of the right size to take the cover off your computer to add the second video card.

Procedure

Install the second video card. For the most part, you will need to follow the instructions that come with the video cards to install them properly. Install them one at a time.

You will need to remove the computer case cover. First, touch some outer metal part of the computer to discharge any static, which could fry your computer's inner electronics. Take the screws out of the case where they hold it on to your computer. These are usually found around the back for towers or desktop computers, but the configuration and placing of screws can be different for each model computer.

Take the cover off your computer. Don't become frustrated if it doesn't come off easily. Continue to touch some external metal on the back of the computer periodically to discharge static shock. Take your new AGP or PCI video card and pop it gently into the slot where it belongs. The length and configuration of the cards and the slots will match.

Each interface card has a retaining screw to attach it to the frame of the case. Locate these screws and gently tighten them. Replace the cover.

Connecting it Up and Turning it On

The instructions with the video cards should mention whether you need to connect the monitors to the computer before, during, or after software installation. If not, make sure connections are made before the next step.

Now it's time to enable dual monitor settings. First, you will need to right click an open area of the desktop on

your computer. Now, left click on Properties at the bottom of the menu that appears. You are

Here you are in the Display Properties about to select the Settings Tab.

Pick a Card, but Not Any Card — DESKTOP CARDS

XP supports at least the following video/graphics cards/adapters, some of which appear with the vendor website. These are for desktop computers.

- www.nvidia.com
Nvidia NV3 (Riva128)
Nvidia NV4, NV5 (TNT, TNT2, TNT2, TNT2 Ultra, TNT2 Vanta, TNT2 M64, Geforce, Geforce3)

- [3DFX Banshee](http://www.3dfx.com)
3DFX Voodoo3, Voodoo4, Voodoo5

- www.ati.com
ATI Rage128, Rage128 AIW, Radeon

- www.3dlabs.com
3DLabs Permedia2, Permedia3

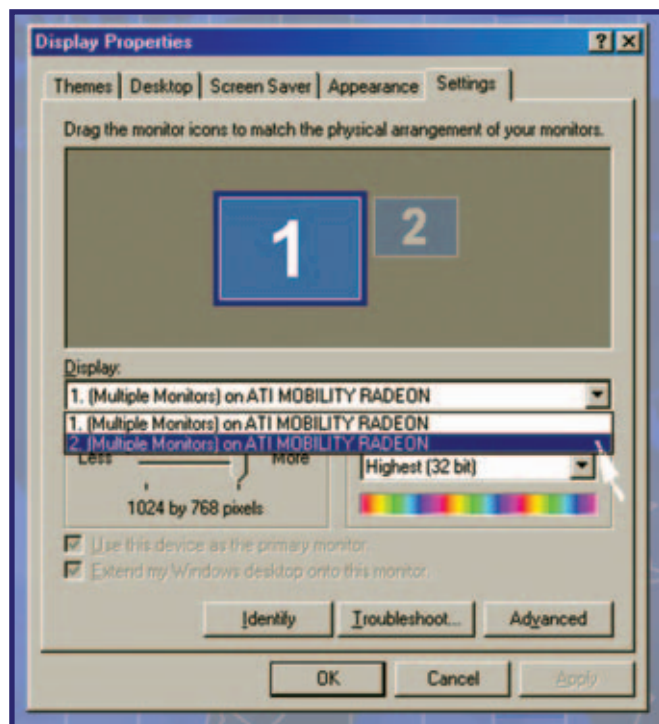
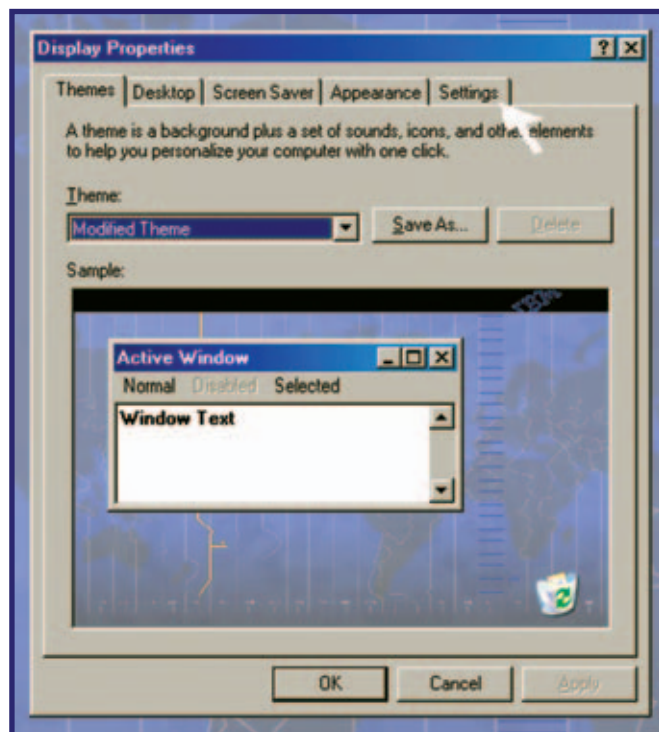
- www.intel.com
Intel I810

- www.matrox.com
Matrox Millennium, Millennium II, Mystique, G100, G200, Productiva, G400, G450

- Number Nine Imagine 128, Imagine128 v2, Revolution 3D, Revolution 4

- SIS315

Here you will select the drop down arrow and monitor number two.



Pick a Card, but Still Not Just Any Card — DESKTOPS WITH XP's DUALVIEW

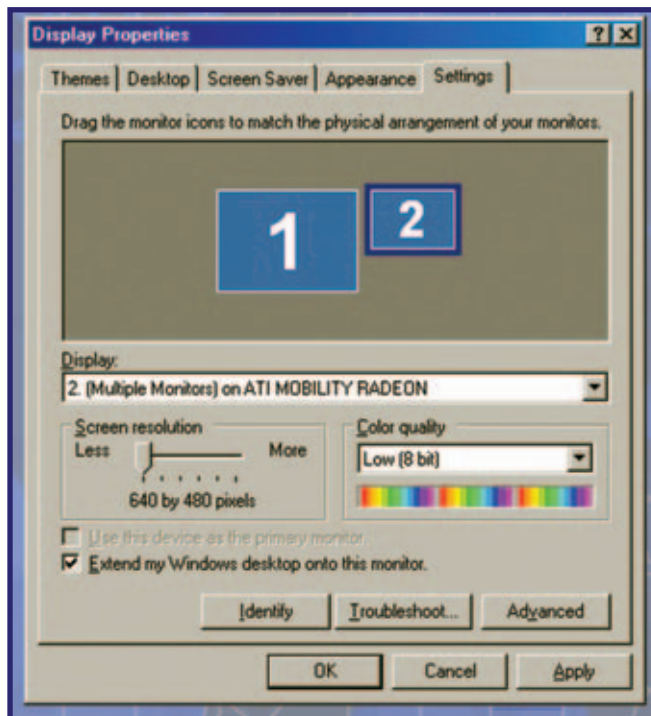
XP supports at least the following video/graphics cards/adapters, some of which appear with the vendor website.

The following cards work with desktop computers that come with XP's Dualview feature:

- SIS300i
- Matrox G200, G400, G450

What's Dualview?

Dualview is a Windows XP technology that lets you use a special single video card for two monitors or a laptop with a port for an external monitor to extend the desktop beyond the current display to an additional screen. This is most useful when extending beyond a laptop screen to a second, external monitor.



Having selected the second monitor here, it appears in the menu window. You will need to check the box next to "Extend my windows desktop onto this monitor" as shown. Then click apply and OK.

of interference, the monitors may need to be moved a little farther apart. Some applications can only be displayed on the primary monitor. Screenshots end up being very large as they capture the entire desktop no matter how big they are.

now in the Display Properties.

Select the Settings tab. Select the down arrow right of the drop down

menu under the word Display in the middle of this screen. Select the second monitor that was added. The second monitor should now appear in the drop down menu window.

Put a check in the box next to "Extend my windows desktop onto this monitor." Click apply and OK, and you're done.

Warnings

If you experience symptoms

Testing

Confirm that you can do all that I described at the beginning of this article. Watch your mouse move from one screen to the other. Open applications and documents and stretch them across both screens or move one to the left and one to the right for multitasking.

Under the same Settings tab, you can select the monitor that you want to adjust settings for and then use the slide bar to change its resolution and the color settings to adjust color.

Future

A number of manufacturers offer mounts for multiple monitors as the dual monitor setup actually affords up to 10 monitors once installed and recognized by your computer. Check out vendors like Ergo In Demand, Ergotron, and the Monitor Outlet.

There is also special software you can try out. Take a look at MaxiVista and UltraMon. These packages can help you to easily set up and configure multiple monitors and get you deep into additional multi-display tweaks and settings.

With MaxiVista, you can turn a networked computer or laptop into a second (or third or fourth or ?) external monitor for multi-monitor setup. UltraMon adds a useful taskbar to each monitor to keep open windows under control. **NV**

Resources

PARTS

1. TigerDirect: www.tigerdirect.com
2. Ergo In Demand: www.ergoindemand.com
3. Ergotron: www.ergotron.com
4. Monitor Outlet: www.monitoroutlet.com

SOFTWARE

1. MaxiVista: www.maxivista.com
2. UltraMon: www.realtimesoft.com/ultramon

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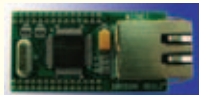
I2C

USB to I2C



USB I2C/IO - Provides a simple "drop-in" solution for connecting your PC to 90kHz I2C + 20 I/O lines. Free software. Use multiple boards for more I2C/IO. **USB I2C/IO \$79**

Ethernet to I2C



NM7010A-LF - Complete, hardwired TCP/IP-I2C module. Offloads stack for hi-speed Internet-enabling microprocessor systems. Drop-in W3100A-based board for instant network speeds to 8Mbps. **\$22**

Ethernet to I2C



FMod-TCP - TCP/IP server with I2C, 19 x digital I/O, 5 x 10-bit A/D inputs, and UART serial interface. Connect I2C devices/sensors to an Ethernet network! **FMod-TCP from \$232**

I2C for PCs



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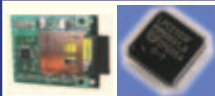
Signal Wizard - easy-use real-time DSP-based filter board for audio bandwidth signals. Design filters in seconds without any DSP knowledge! **Signal Wizard 2.5 \$499**

FPGA systems



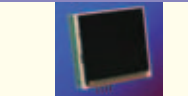
Hunt Eng - RTG005 a new, self-contained ready-to-go FPGA system with CameraLink connection. Makes an ideal starter kit for developing image processing systems. **RTG005 from \$2995**

FATfile Storage



Micro ALFAT-SD - Ready-made way to easily add SD storage to your product. Serial data in - FATfile data out. **\$39.95** Or design-in a micro ALFAT IC for MB storage - **\$14 ea.**

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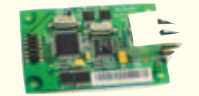
Ethernet

Serial-Ethernet Cable



28" cable links serial devices to network without a PC, gives your product an instant IP address. 115Kbaud RS-232 port compatible with most 10/100Mbps Ethernet hubs. Network your serial product easily! **eCOV-110-P \$99**

Ethernet to Serial



EG-SR-7150MJ - Ready-to-go serial-to-Ethernet Gateway. Simple set-up for 10/100Mbps Ethernet - 230kbps serial. Ethernet/Internet-enable any serial part. **EG-SR-7150MJ \$35**

Ether-IO



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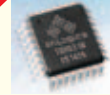
Bluetooth



Emxys PearlBlue - 100m-Bluetooth module (UART master/slave bridge). Easy connection for micro's to PCs, PDAs, phones, etc. IceBlue - PIC16F877 based emb. dev. system for shortest Bluetooth development. **\$119**

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Data Modem



Data Modem - USB-powered radio transceiver boards add wireless RS232 to your device! Get remote control for your product from PC USB port! **RTM-USA \$89**

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Byteparadigm - Fast USB 2.0 multichannel input or output/ arbitrary digital waveform generator/ logic analyzer. 100MB/s burst; thruput to 48MB/s, 22 x I/O. **GP-22050-BASE \$1187**

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THE NUTS & VOLTS OF PODCASTING

by Edward B. Driscoll, Jr.

Over the past couple of years, podcasting has emerged as one of the great new buzzwords of the Internet, bringing the same freedom to create personal audio and video productions as Weblogs did for text at the start of the decade. (And for a primer on that topic, see our article in the July '05 issue of *Nuts & Volts*.)

But perhaps even more so than blogs, podcasting takes a few moments to explain, both in terms of its general concept, and its benefits. Podcasts can be a great way to use audio — and increasingly, video — to express your interests and hobbies. They're not for everyone, of course — some people make much better writers than talkers, which is why text-based blogging isn't going away anytime soon. But for those who are better talkers than writers, they're worth experimenting with. And a heck of a lot of fun, to boot.

What is Podcasting?

The MP3 file was invented in the early 1990s as an Internet-friendly way to save and distribute speech and music. A three-minute song takes up dozens of megabytes of space on a compact disc; saved as an MP3 file, its size is typically a much more manageable three to eight megabytes. Internet surfers equipped with increasingly ubiquitous broadband, can use their Internet connection to quickly download MP3 files.

Beginning in 2004, with the success of the Apple iPod (Apple claims sales of over 67 million iPods) and numerous other MP3-oriented portable media players, the word "podcasting" took off as a way to describe self-contained shows geared

towards listeners with portable MP3 players.

However, the term is somewhat of a misnomer. An Apple iPod is not required to listen to podcasts, as many competitors make devices that can also play MP3 files. And indeed, a portable MP3 player itself isn't required; virtually every modern desktop and laptop computer can download and play an MP3 file, via Windows Media, Apple QuickTime, Real Media, and other programs. And that's a huge audience that can be potentially reached with one uploaded MP3 file.

What Should a Podcast Contain?

Since it's merely an MP3 file, a podcast can be anything from a three-minute song, to freeform anarchy. However, the format has emerged as a way to easily send prerecorded speech over the Internet. In other words, you can record anything from a short personal greeting to a whole news or interview show and distribute it virtually without cost.

Someone wishing to create a hobby-oriented podcast on the topic of building electronic projects might want to combine the following elements:

- Opening and closing theme music.

- Spoken word introduction.
- Description of a project or engineering issue.
- Telephone interviews with friends or interesting guest experts.
- Bumper music to open and close the show, and separate segments.

Let's explore the basics of how to record all of these components.

The Three Elements of Podcasting

Podcasting requires three separate building blocks: recording the podcast; uploading it; and then sharing the news of its creation with the rest of the online world.

While it's possible to record a podcast with a traditional analog audio recorder and then convert it afterwards via computer to an MP3 file, the vast majority of audio podcasts are recorded via computer. It doesn't matter which program you use to do the actual recording, as long as the finished product is saved as an MP3 file.

For those with a background in PC music recording, the audio portion of a podcast should be pretty simple. Currently, I'm using Cakewalk's Sonar 6 (www.cake

walk.com), a powerful, professional Windows-based recording program. It's overkill for podcasts, but its editing capabilities and compatible plug-in filters can give a podcast a slick, professional sheen.

For those using Apples, recording a podcast is even easier. In 2005, Apple expanded their popular GarageBand recording program, currently shipping pre-installed on new Macintosh PCs, to incorporate all of the main software elements required for podcasting. In 2006, they even added prerecorded jingles and bumper music, and the ability to integrate with their iChat program to record audio and video discussions with other iChat users.

Whichever format you prefer, the recording of the various elements that make up a typical podcast are much the same. While the following is geared to those using Windows-based PCs, Apple users should be able to

with professional low impedance XLR-connectors to connect to a Windows or Macintosh PC via USB. Just buy a second microphone (such as Shure's classic SM-58, which has been around for literally decades, and retails for about \$100) and you've just transformed your PC into a small recording studio.

Another option (which Apple's Xander Soren, their GarageBand product manager is keen on) is Blue Microphone's (www.bluemic.com) slick-looking Snowball mic, which combines beautiful 1930's aesthetics (think Orson Welles and the Mercury Theater) with modern frequency response, and a USB interface. "It's been looked at as a kind-of breakthrough product that has brought professional-sounding microphones to a hobbyist price point," Soren notes. "I think they sell for about \$149."

Getting audio from a telephone

elements of the podcast in real-time, especially as you're getting starting. In other words, you don't have to record your show's opening, then immediately switch to a telephone interview, then record the closing speech, all on the fly. The beauty of digital audio in a PC is its editing flexibility.

The same techniques that allow teenybopper MTV singers to deliver stunning performances by cutting together the best parts of multiple recording takes can be adapted to making your own podcast sound great. It's possible to seamlessly edit together the best parts of multiple takes of a single speech, cut out coughs, "umms," and "you knows," as well as simply take the best parts of an interviewee's comments and discard the boring bits.

Also, many recording programs have plug-in filters such as EQ and noise gates, which can tame an

“Podcasts can be a great way to use audio — and increasingly, video — to express your interests and hobbies.”

adopt all of the following concepts, as well.

• **Opening and closing theme music:**

There are numerous ways to import music into a podcast. If you or a friend are any kind of musician, you can record a jingle in-house. Or, you could look for existing royalty-free recordings (the type that are used for movie soundtracks on a budget), or if you want to spend the money, license an existing commercial recording.

• **Spoken word introduction and interviews:**

To record audio, you'll need one or two microphones and a way to import them into the PC. M-Audio (www.m-audio.com) produces a variety of soundcards, as well as an affordably priced Podcast-Factory kit. It contains a microphone, some software, and a breakout box that allows mics

interview into the computer is a bit more problematic if you're seeking professional results. JK Audio, Inc. (www.jkaudio.com), makes a Telephone Audio Inline Patch, which converts telephone signals to audio, and then sends it out via XLR and miniplug cables. This box could easily be plugged into the M-Audio interface mentioned above, to enable your computer to record telephone calls.

Another option is Skype (www.skype.com), an increasingly popular Internet telephony program that also has conference call features. However, it will need to be bundled with a recording applet that's Skype-compatible; one such program is downloadable from HotRecorder.com.

• **Digital Editing:** It's probably best not to try to bring together all of the

initially noisy recording. Recording telephones, as well as location recording, can be frustrating, with hiss, hum, and other background noise making a clean recording difficult. Consumer-oriented software products such as Bias, Inc.'s, SoundSoap 2 (www.bias-inc.com) are a good first step towards filtering out this subsurface gunk, and their higher-end SoundSoap Pro — with its much more interactive and advanced GUI — does an even more thorough job. Carefully applied, it can make what was initially a noise-filled conversation sound remarkably pristine.

Hosting and RSS Feeds

Once the podcast is recorded and edited, it's time to save it as an MP3 file and upload it to your website. While there are many ways to accomplish this, one simple method

Moving Pictures

Apple's iTunes format for podcasting supports both the MP3 audio-only format and also the MP4 format, which allows for audio and video. Which means that video podcasting (or v-casting, for short, and it's sometimes referred to as v-blogging), is a perfect way to show off or share your projects.

Video podcasting builds on the recording tips discussed here, but as the name implies, adds pictures to the mix. Note that they need not be moving pictures. It's possible to make an effective video podcast by adding a slideshow of digital still photos or even schematics to an audio track.

For the technologically savvy electronics hobbyist, V-blogging seems like a natural: step-by-step walkthroughs of newly completed projects, hands-on tests of new equipment, and a mix of video and still photo electronic slideshows are all possible with videocasting. Silent video or still photos could be mated with narration to provide a very slick, compelling presentation, complete with graphics.

Apple users have a real headstart here, as GarageBand has a complete video podcasting applet built into it. For PC-users, programs such as the latest incarnation of Adobe's Premiere Elements provide most of these same functions.

Even more so than with an audio podcast, production values are key with video. With audio, much can be done on a low budget to improve audio quality. There's less room for error with video, though. Experiment with it, but if your production values aren't up to snuff, stick with audio for now, until — and if — you perfect the video side of things.

would be create a directory called "Podcasts" on your site to hold the audio files that have been created. Any one of hundreds of simple FTP programs can be used to upload the file to the site.

Telling the world about your podcast is accomplished through what is called an "RSS feed." RSS stands for Really Simple Syndication, and was originally created in the late 1990s and early "naughts" to allow news services — and later bloggers — to

easily alert others of new articles or posts. (One popular use of RSS allows web users to customize their homepages — such as **My.Yahoo.com** — with their favorite newsfeeds, from literally any website that supports the RSS standard.) An RSS feed on your uploaded podcast is what makes it searchable and distributable.

Apple's iTunes website (**www.apple.com/itunes**) has emerged as the Big Daddy of podcasting syndication, with over 200 million copies of

the iTunes software distributed, according to Apple. iTunes — and most other podcast sharing websites — use RSS feeds to make users aware that new podcasts about a specific subject are online.

To facilitate podcasting, Apple promotes their own modified version of RSS, which contains additional information not found in the normal RSS feed, including the name of the audio file being podcasted ("rc_car_building.mp3," for example), its author, description, and file size. **Yahoo.com** — which has its own podcast-oriented section — has an excellent how-to guide for podcasting, including how to create this iTunes-specific modified RSS feed. It's currently at **podcasts.yahoo.com/publish**. *Wiley Publishing's Podcasting For Dummies*, by Tee Morris and Evo Terra, also explains how to create this type of feed, along with loads of other tips.

Spreading the Word

If your goal is simply to learn a new skill and move on, that's fine. But it's much more enjoyable to think of your podcast as a series to be released on a regular basis (possibly weekly, just like most network TV shows), so that your website's readers and your newfound podcast listeners get used to knowing that you have new shows rolling out on a regular schedule.

Apple's Xander Soren reminds us that "First there was broadcasting, and it was very expensive. You needed to have a lot of infrastructure in place, and it was a major investment for the networks to reach a large market." "But the really amazing thing about podcasting," Soren adds, "and the reason why it's taken off, is that it democratizes communication. So anyone with a message or a story can essentially create their own narrowcast channel. They basically have access to a worldwide audience."

You may not want a worldwide audience, but given the numbers involved, and the extremely low cost of entry, why not reach some people who share your interests? **NV**

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■ BY JON WILLIAMS

LIVIN' LIFE ON THE SX28

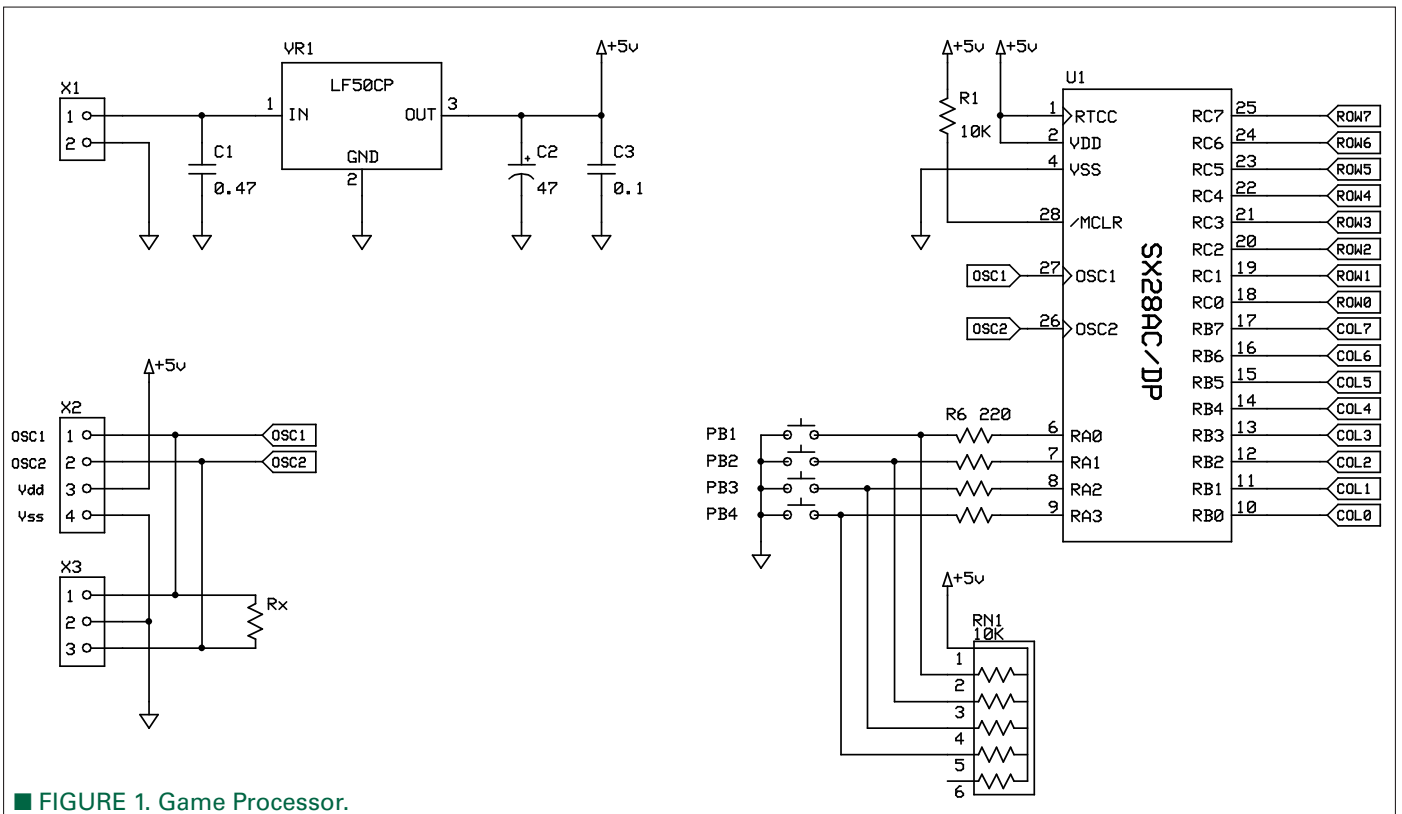
IT OCCURRED TO ME THE OTHER DAY that I've been programming in one form of Basic or another for over 25 years now ... wow, that seems like a long time! I taught myself to program on the venerable Timex-Sinclair 1000, my first "real" computer, which I purchased in the fall of 1981. One of my favorite TS-1000 programs was a version of Conway's Game of Life — a simple artificial life simulation. I used to start the program before work and was always excited to come home and see if the "colony" was still evolving, had reached a state of equilibrium, or had just died. Honestly, I was always saddened when the latter event occurred — imagine being saddened by the "death" of a simulated cell colony ... welcome to my wackiness!

Conway's Game of Life (CGoL) is a very simple program, and though it's been around since the '70s, it is still considered an important learning tool. I was telling my friend, Ryan Clarke, a

professor at the University of Advancing Technology in Phoenix about this project and he told me that there are at least two courses on their campus that use CGoL as part of the

curriculum. That's the thing about CGoL; it's simple, it's elegant, and yet it has implications in so many fields from basic gaming to advanced robotics.

In case you've never seen CGoL,



■ FIGURE 1. Game Processor.

it works like this: A rectangular grid serves as the home of a digital cell colony. A set of rules are applied that cause the colony to evolve from generation to generation. Ultimately, the colony with either:

- 1) Die (no living cells).
- 2) Live in static equilibrium (no cells change).
- 3) Live in dynamic equilibrium (cells change in a repeating pattern).

The rules that drive inter-generation change are simple, and are based on the number of living “neighbors” that surround each cell.

- 1) With one or less neighbors, the cell dies (of loneliness).
- 2) With two neighbors, there is no change in the cell state.
- 3) With three neighbors, the cell lives.
- 4) With four neighbors, the cell dies (of over-crowding).

For me, there are few more compelling programs than Conway’s Game of Life. My rediscovery (running Java versions online) of CGoL caused me to wonder if I could translate it to the SX. It was easy on the TS-1000 (or other “big” PC), but the SX28 (using SX/B) doesn’t support multidimensional arrays and that’s a requirement to manage the cell colony grid.

I decided to give it a shot for two reasons: First, it would just be plain fun and would allow me to incorporate some electronics into one of Joshua’s (my youngest brother) paintings. Second, it would give me a reason to build a platform to experiment with discrete LED multiplexing. In fact, I could build a very generic circuit that would, essentially, be a mini game console and CGoL would be the first demo. So, that’s what I did.

The circuit is easy, and by using the SX28, the logical size of the grid is 8x8; this allows us to use the pins on RB to control the LED cathodes and the pins on RC to control the LED

anodes. This leaves the pins on RA available for button inputs; again, the circuit is generic and can be used for a whole host of experiments. Figures 1 (processor and buttons) and 2 (LED matrix) show the schematic.

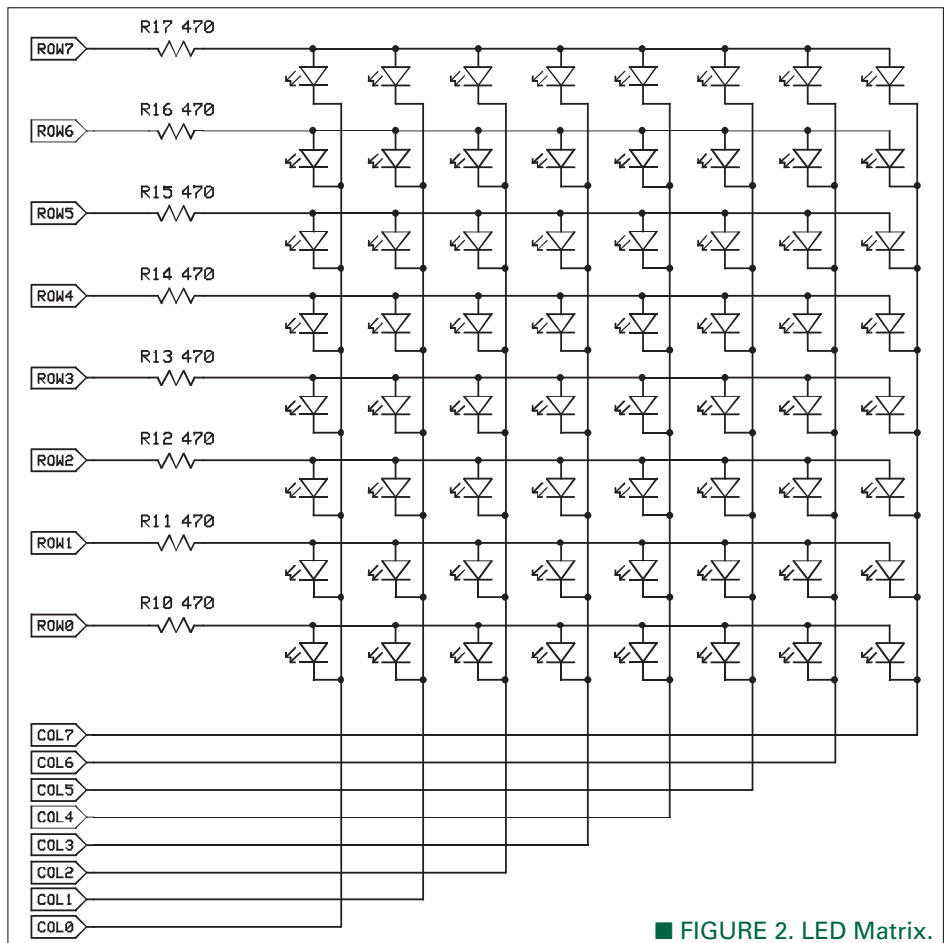
Now, I’m pretty good with a soldering iron, but there was no way in heaven or on earth that I was going to connect the processor and 64 discrete LEDs using point-to-point wiring. If you choose to go that route, you’re a braver soul than me. As with the Pinewood Derby Lane Timer we made in January, I entered the circuit in ExpressSCH and then created the board in ExpressPCB.

I may have made this statement before, but I think it’s worth repeating: DO NOT — under any circumstances — be tempted to skip past ExpressSCH and go right to ExpressPCB. It’s not that I lay out a lot of boards, but I had tried ExpressPCB way back before ExpressSCH was part of the package, and while the PCB layout program is very nice and easy to work with, the value in connecting to a schematic

[netlist] as an aid to the PCB layout cannot be overstated.

Of course, for this project — should you like it as-is — you don’t have to worry about that as I’ve already done the layout work (which took about eight hours). But ... if you decide to make a change, copy and modify the schematic first, then open and copy the PCB file, finally linking it to the new schematic. Make your PCB changes from there, allowing ExpressPCB to tell you what connects to what. Please trust me on this as there is nothing more frustrating than spending time on a nice, neat PCB layout, only to find that when it gets back from the board house there’s a self-created error.

For circuit components, I tend to order from Mouser. When I lived in Dallas, I had the opportunity to visit their facilities and it is really a first-class operation. Their prices are good, too. Of course, vendors like Jameco also provide great products and service. I just want to let you know that the schematic file that you can download



■ FIGURE 2. LED Matrix.

as part of this article includes Mouser part numbers. There is nothing exotic, though, and you should be able to get the components anywhere.

Construction is easy — it's really just a big solder job. As always, I start with the "low lying" components (e.g., resistors) and work my way up to the taller components, like the power-supply cap and the power connector. I started by soldering in everything except the LEDs. Despite my confidence in the schematic and the board, I certainly wasn't going to spend the time to solder in 64 discrete LEDs only to find I had screwed up. With everything but the LEDs in place, I connected power and downloaded a little test program to poll and display the status of the switch inputs (I used the Debug window for this). Guess what? I actually had a duff SX (one pin on RA, anyway).

After I knew the power supply and buttons worked, the next step was the LEDs. Being a cautious guy, however, I soldered them in eight at a time and then ran a quick test program to make sure that those in the board were working. In the end, everything worked perfectly and it was time to start on the Game of Life program.

CREATING DIGITAL LIFE

In order to use the 8x8 LED matrix as a display for the game, it needs constant (periodic) refreshing — a logical choice is to use an interrupt. To keep things easy, I decided on a one millisecond interrupt period; there is nothing magic about that value except that it's a convenient way to enable fairly precise delays.

Wait a minute, what about **PAUSE**? Well, remember that when we activate periodic interrupts, any timing-sensitive instructions will be adversely affected. So, you'll see that there is no **PAUSE** instruction used in the program, and yet there is a way to do delays with millisecond (+0/-1) resolution.

Let's have a look at the interrupt code.

```
INT_HANDLER:
  Anodes = %00000000
  READ Col_Mask + col, Cathodes
  Anodes = dispBuf(col)
  INC col
  IF col = 8 THEN
    col = 0
  ENDIF

Update_Timer:
  IF ms > 0 THEN
    DEC ms
  ENDIF

LFSR:
  IF seed = 0 THEN
    seed = 24
  ENDIF
  ASM
    MOV W, #$1D
    CLRB C
    RL seed
    SNB C
    XOR seed, W
  ENDASM

ISR_Exit:
  RETURNINT
```

As you can see, the ISR code is divided into three distinct elements: display update, timer update, and random value update. First things first. The bits to be displayed are kept in an array called *dispBuf()*; with eight bytes, this gives us a 64-bit (8x8) array for the colony. The orientation of the LEDs on the board is designed to match Cartesian coordinates, that is, the lower left LED corresponds to *dispBuf(0)*, bit 0, and the upper right LED corresponds to *dispBuf(7)*, bit 7.

The display update starts by clearing the anode outputs and then reading the column mask from a **DATA** table (using the current column value). I like the table approach versus creating a mask by bit shifting; it seems more obvious and I think it adds a bit of flexibility. With the column selected, the anodes are read from *dispBuf(col)*; at this point, the column is being displayed (until the next ISR call). Then, the column pointer is incremented and wrapped back to zero once it passes the seventh column. Note that the variable, *col*, should not be manipulated outside the ISR.

The second section updates another dedicated ISR variable called *ms*. This variable is a word (16 bits) so that we can create delays up to 65,535 milliseconds. Through each pass of the ISR, this variable is checked for being non-zero; when it is, it gets decremented. We'll see how to use this value in place of **PAUSE** in just a bit (no pun intended).

Finally, there is a section called **LFSR** (which stands for *linear feedback shift register*). In this program, it is used to randomize the third dedicated ISR variable called *seed*. When I first started the program, I used the built-in **RANDOM** function but found that the results weren't visually pleasing. So, I went out to James Newton's SX List (www.sxlist.com, an excellent resource) and found an eight-bit LFSR routine that gave me the visual results I was looking for (again, no pun intended).

You might wonder why this is embedded in the ISR. Of course, I could have created a traditional function, but I thought it would be nice to have a running random number. As you can imagine, I work with a lot of folks that are new to BASIC Stamps and the SX and the interesting thing is that many of them believe that the **RANDOM** function is a "background" process that runs all the time. Well, in this case, it is. We simply need to copy the value of *seed* whenever we want an eight-bit random number.

SCROLLIN', SCROLLIN', SCROLLIN' ...

As one of the possible uses for the 8x8 LED matrix is a scrolling display, let's add that to the front end of the game program to make things a bit snazzy. Sticking with the KISS principle, we'll store the scrolling banner in a big **DATA** table and simply loop through it; the effect is an 8x8 window sliding over the banner as shown in Figure 3. Note that there are eight blank columns on either end of the banner text; the front-end

■ FIGURE 3. Scrolling Display.

blanks let the banner scroll on to the display; the back-end blanks push it off.

The arrows above the figure indicate the starting and ending columns for the main portion of the loop. An inner loop will iterate from that starting point out seven additional columns to fill the display buffer. Here's the code:

```
Start:
  ` scrolling banner
  FOR tmpB1 = 0 TO 45
    tmpB2 = tmpB1
    FOR idxCol = 0 TO 7
      READINC Banner + tmpB2, dispBuf(idxCol)
    NEXT
    DELAY 75
  NEXT
```

The outer (scrolling) loop is controlled by *tmpB1*. A copy is made in *tmpB2* that will be used as an offset for the **READINC** function. The inner loop, controlled by *idxCol*, runs eight times to fill the eight columns of the display with values from the **DATA** table. The nice thing about the **READINC** function is that it automatically updates the offset variable (*tmpB2*) for us. Once the display buffer is filled, we need to insert a short delay to control the column-to-column scrolling speed.

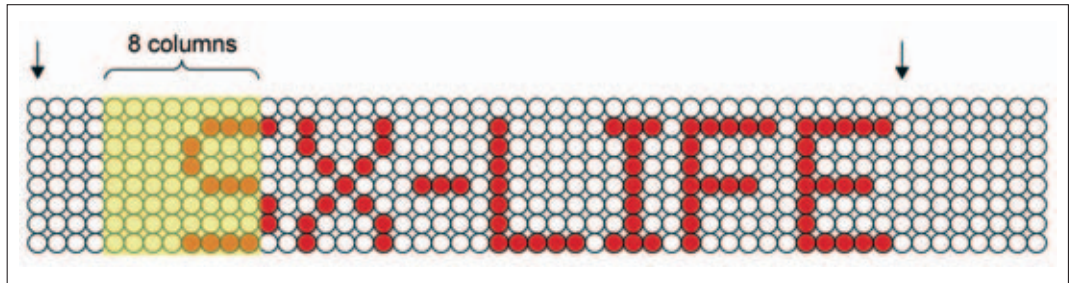
Here's the delay subroutine that replaces the use of **PAUSE** in this program.

```
DELAY:
  IF __PARAMCNT = 1 THEN
    ms = __PARAM1
  ELSE
    ms = __WPARAM12
  ENDIF
  DO
    ` wait for timer to expire
  LOOP UNTIL ms = 0
  RETURN
```

Pretty simple, isn't it? The subroutine is set up to allow a byte or word to be passed to it. That value gets loaded into variable *ms* and then a **DO-LOOP** holds the program right where it is until *ms* is zero. Remember, *ms* is being decremented every millisecond in the ISR when it's greater than zero. This is a good bit of code for your SX/B library, especially as you delve more deeply into interrupts.

FRAMED!

We've just seen one style of animation, how about another — something akin to cell animation in a cartoon. We can do this kind of animation by storing the frames in a



DATA table. For frames that are going to run in order (as we will do here), the code is assisted by lining up the frames end-to-end. Figure 4 shows a simple four-frame sequence that will run after the scrolling banner moves out of the display.

```
Frames_Animation:
  FOR tmpB1 = 0 TO 24 STEP 8
    tmpB2 = tmpB1
    FOR idxCol = 0 TO 7
      READINC Frame1 + tmpB2, dispBuf(idxCol)
    NEXT
    DELAY 100
  NEXT
```

It's clear that the code is identical to the scrolling animation except that the outer loop steps eight columns (one frame) each time through, and the base pointer starts at **Frame1** instead of **Banner**.

Now that the fanfare is complete, we can get into the meat of the Game of Life program. At the start of the main program loop, a question mark will be displayed and then the buttons scanned.

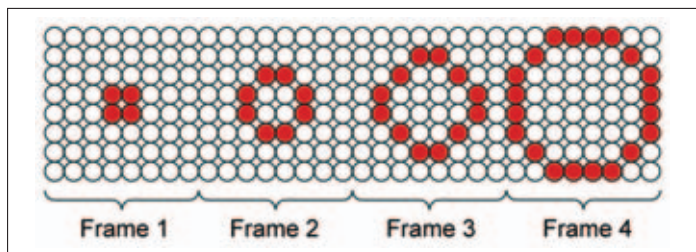
```
Main:
  FOR idxCol = 0 TO 7
    READ Q_Mark + idxCol, dispBuf(idxCol)
  NEXT

User_Select:
  DO
    btns = SCAN_BUTTONS
  LOOP UNTIL btns <> %0000
```

Here's the routine that scans and debounces the buttons.

```
SCAN_BUTTONS:
  tmpB1 = %00000000
  FOR tmpB2 = 1 TO 5
    tmpB1 = tmpB1 | BtnPort
    DELAY 10
  NEXT
  tmpB1 = tmpB1 ^ %11111111
  tmpB1 = tmpB1 & %00001111
  RETURN tmpB1
```

The buttons are configured as active-low inputs to the SX so the subroutine starts by clearing the result variable, *tmpB1*. It then runs a short loop with a 10 millisecond pad between scans. With active-low buttons,



■ FIGURE 4.
Animation Frames.

The next two buttons load fixed colony patterns from **DATA** tables.

The first pattern loads “blinkers” that will oscillate in a state of dynamic equilibrium. The second pattern is called a “glider.” It will move from the lower left corner to the upper right corner, ultimately achieving a state of static equilibrium (a living colony that does not change from one generation to the next).

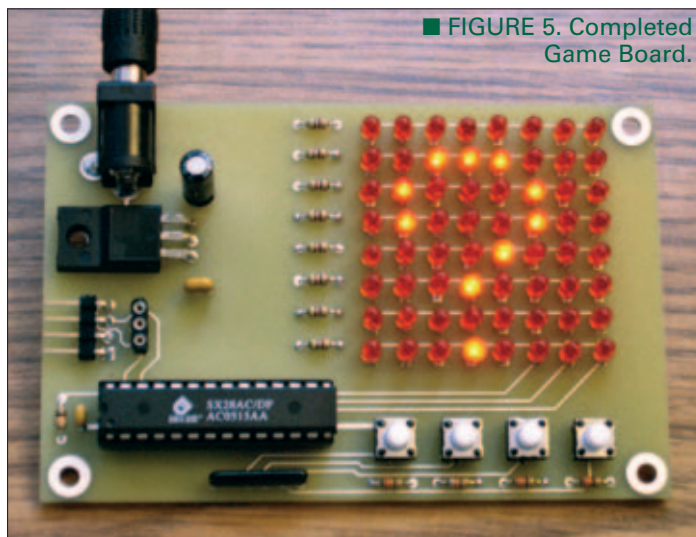
a short release (bounce) will cause the input to go high (because of the pull-up) and the 1 bit will get OR'd into the result; this will stay there through the entire scan cycle.

At the end, the scan result gets inverted to make the buttons look active-high and the unused inputs are stripped away. The design of this function ensures that a button must be down and stay down for 50 milliseconds to call it a good press. Using the loop to check the switch state at short intervals helps eliminate contact bounce and noise.

With the switches scanned and debounced, the program can check for and process valid “press” events. The first button will cause the cell matrix to be randomly populated.

```
Randomize_Cells:
  IF btms = B_RAND THEN
    FOR idxCol = 0 TO 7
      dispBuf(idxCol) = seed
    NEXT
    DELAY 5
    DELAY 50
    GOTO User_Select
  ENDIF
```

Here you can see the use of the system random value, *seed*. Note that there is a short delay in the middle of the cell-populating loop; this lets the LFSR code in the ISR run a few times between calls. A short delay is also added after the loop just to hold the display a bit if the randomizing button is held down.



■ FIGURE 5. Completed
Game Board.

```
Load_Pattern1:
  IF btms = B_PAT1 THEN
    RELEASE
    FOR idxCol = 0 TO 7
      READ Pattern1 + idxCol, dispBuf(idxCol)
    NEXT
    GOTO User_Select
  ENDIF

Load_Pattern2:
  IF btms = B_PAT2 THEN
    RELEASE
    FOR idxCol = 0 TO 7
      READ Pattern2 + idxCol, dispBuf(idxCol)
    NEXT
    GOTO User_Select
  ENDIF
```

As it stands now, the program only has two fixed patterns in memory. If you want to add more, then change the code to keep track of a pattern pointer and use the PB2 and PB3 buttons to increment or decrement that pointer before loading the pattern.

The last button launches the game with generation zero being whatever the display is current showing — including the initial question mark prompt. This section also handles getting back to the button scanning if more than one button was pressed.

```
Run_Simulation:
  IF btms = B_RUN THEN
    RELEASE
    GOTO Its_Alive
  ELSE
    GOTO User_Select
  ENDIF
```

Within the button handlers, there is a subroutine employed called **RELEASE**. This is used to hold the program until the buttons are cleared.

```
RELEASE:
  DO
    tmpB1 = SCAN_BUTTONS
  LOOP UNTIL tmpB1 = %0000
  RETURN
```

As you can see, this routine uses a work variable (*tmpB1*) so the result of our last button scan (*btms*) is not affected.

And now we get to the nitty-gritty. The code at **Its_Alive** is what runs the game logic. What this section does is iterate through all of the cells of the display buffer,

counting the neighbors for each. The rule set is applied and the results are written to a secondary buffer called *newGen()*. We can't operate directly on the display buffer as this would change the colony mid generation and the results would not accurately reflect the rules. Once all of the cells in the display buffer have been scanned and analyzed, the *newGen()* buffer is copied to the display. After a scan of the keys and short delay, the whole process starts over.

```

Its_Alive:
  FOR idxCol = 0 TO 7
    FOR idxRow = 0 TO 7
      COUNT_NEIGHBORS
      IF neighbors <= 1 THEN
        ' alone... dies
        newGen(idxCol) = 0
        CLR_BIT newGen(idxCol), idxRow
      ENDIF
      IF neighbors = 2 THEN
        ' no change
        cell = GET_BIT dispBuf(idxCol), idxRow
        newGen(idxCol) = cell
        PUT_BIT newGen(idxCol), idxRow, cell
      ENDIF
      IF neighbors = 3 THEN
        ' lives!
        newGen(idxCol) = 1
        SET_BIT newGen(idxCol), idxRow
      ENDIF
      IF neighbors >= 4 THEN
        ' crowded... dies
        newGen(idxCol) = 0
        CLR_BIT newGen(idxCol), idxRow
      ENDIF
    NEXT
  NEXT

  FOR idxCol = 0 TO 7
    dispBuf(idxCol) = newGen(idxCol)
  NEXT

  DELAY 200
  btns = SCAN_BUTTONS
  IF btns = %0000 THEN Its_Alive
  RELEASE
  GOTO Main

```

I moved the code for **COUNT_NEIGHBORS** out of the main loop because it was just very big and bulky. I tried to figure out some elegant way to do the testing, but in the end, found that it was simply best to use a bit of blunt force. It's long so I won't show the whole thing here, but what you'll see when you download the full listing from the *Nuts & Volts* website (www.nutsvolts.com) is that **COUNT_NEIGHBORS** has eight sections that look like this:

```

chkCol = idxCol - 1
chkRow = idxRow - 1
cell = GET_CELL
neighbors = neighbors + cell

```

You see, each cell has eight possible neighbors — but not all cells; the corner cells, for example, only

have three neighbors. To deal with this, I created a routine called **GET_CELL** which is really just a wrapper for **GET_BIT**. The code in **GET_CELL** ensures that we don't try to ask for a bit that exceeds the bounds of the array.

```

GET_CELL:
  tmpB1 = 0
  IF chkCol >= 0 THEN
    IF chkCol <= 7 THEN
      IF chkRow >= 0 THEN
        IF chkRow <= 7 THEN
          tmpB1 = GET_BIT dispBuf(chkCol), chkRow
        ENDIF
      ENDIF
    ENDIF
  ENDIF
  RETURN tmpB1

```

Those of us that have been using the BS2 family for a long time are well aware of and enjoy the use of the **.LOWBIT()** modifier of variables — this does not exist in SX/B. Well, not as part of the standard language, so we just have to add it (or something like it) ourselves.

To get **.LOWBIT()** functionality actually requires three separate functions; they're actually very simple and provide a bit more flexibility than **.LOWBIT()**. These functions expect a byte and return a byte; this lets us send the result to any variable we choose, including to the

► BILL OF MATERIALS FOR PROJECT

Item	Description	Source
► C1	0.47 µF	Mouser 80-C320C474M5U
► C2	47 µF	Mouser 647-UVR1C470MDD
► C3	0.1 µF	Mouser 80-C315C104M5U
► D1-D64	LED	Mouser 859-LTL-4222N
► PB1-PB4		Mouser 612-TL59F160Q
► R1	10K	Mouser 299-10K-RC
► R6-R9	220Ω	Mouser 299-220-RC
► R10-R17	470Ω	Mouser 299-470-RC
► RN1	10K	Mouser 264-10K-RC
► Rx		(optional)
► U1	SX28AC/DP Socket	Parallax SX28AC/DP-G Mouser 571-3902619
► VR1	LF50CP	Mouser 511-LF50CP
► X1	2.1 mm	Mouser 806-KLDX-0202-A
► X2	For SX-Key	Mouser 517-5111TG
► X3	For Resonator	Mouser 506-510-AG91D
► PCB		From ExpressPCB.com

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jwilliams@efx-tek.com

PARALLAX, INC.
www.parallax.com
www.sxlist.com

http://en.wikipedia.org/wiki/Conway's_Game_of_Life

variable whose value was passed as a parameter to the function.

GET_BIT:

```
tmpB1 = __PARAM1
tmpB2 = __PARAM2

tmpB2 = 1 << tmpB2
tmpB1 = tmpB1 & tmpB2
IF tmpB1 > 0 THEN
    tmpB1 = 1
ENDIF
RETURN tmpB1
```

SET_BIT:

```
tmpB1 = __PARAM1
tmpB2 = __PARAM2

tmpB2 = 1 << tmpB2
tmpB1 = tmpB1 | tmpB2
RETURN tmpB1
```

CLR_BIT:

```
tmpB1 = __PARAM1
tmpB2 = __PARAM2

tmpB2 = 1 << tmpB2
tmpB2 = tmpB2 ^ %11111111
tmpB1 = tmpB1 & tmpB2
RETURN tmpB1
```

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All three functions take the byte parameter into *tmpB1* and the position value into *tmpB2*. The position value is turned into a bit mask for that position. For bit checking or setting, the mask is left as-is; for bit clearing the mask gets inverted. The functions only work on bytes, but could easily be modified to work with words.

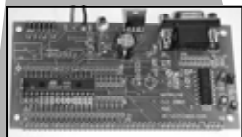
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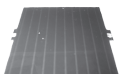
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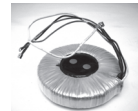
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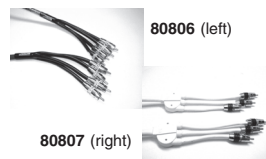
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■ BY PETER BEST

USING ETHERNET INSIDE A PIC

THE MICROCHIP FOLKS OFFER A FREE TCP/IP STACK that works very well with the PIC18F67J60. That sets Microchip up a notch in my book, as there's nothing better than a semiconductor manufacturer that offers a free support firmware package for its products. However, not every embedded Ethernet design needs DHCP or TCP capabilities. For instance, if you only need UDP, in most cases, you'll still need to load all or the bulk of the stack's underlying components which go unused and eat up your microcontroller's precious Flash and SRAM resources. About the only way around that situation is to write your own set of PIC18F67J60 drivers, and that's just what we're going to do in this spin of Design Cycle.

GOING ABOUT IT

The free Microchip TCP/IP stack supports both the Realtek RTL8019AS and their own new ENC28J60 stand-alone Ethernet controller, as well as the PIC18F67J60 and all of its big brothers. As we progress through the process of putting together a set of PIC18F67J60 driver routines, I will pull heavily from Fred Eady's Realtek RTL8019AS garage stack that has proven itself over the years. After all, once you lay down the basic firmware for performing ARP and UDP processes, you can apply those same principles across platforms.

Thus, once the new PIC18F67J60 driver firmware is assembled, there is no reason that I can think of which will prevent the Internet protocol code that works for the RTL8019AS and ENC28J60 to work with the PIC18F67J60. You can gain a better understanding of Fred's RTL8019AS code by getting yourself a copy of his book on the subject entitled *Networking and Internetworking with Microcontrollers*.

Most of my days are spent doling out advice to readers about embedded Ethernet via email messages. When I'm

not responding to reader emails, I'm thinking about or designing new stuff. Recently, I've seen reader interest shift from the RTL8019AS-based technology to the new Microchip Ethernet engine technology. The Microchip folks provided an easy out for us with regards to the ENC28J60 as they provided a full TCP/IP stack for their new parts up front.

Although that was a good thing for all of us, rather than try to adapt the Microchip TCP/IP stack, I've decided to offer some homebrewed "garage" PIC18F67J60 drivers to fit our special PIC18F67J60 hardware. If you need the full power of the Microchip TCP/IP stack, it will run on the PIC18F67J60 hardware I presented in the previous portion of this set of Design Cycle columns.

CODING THE I/O SUPPORT ROUTINES

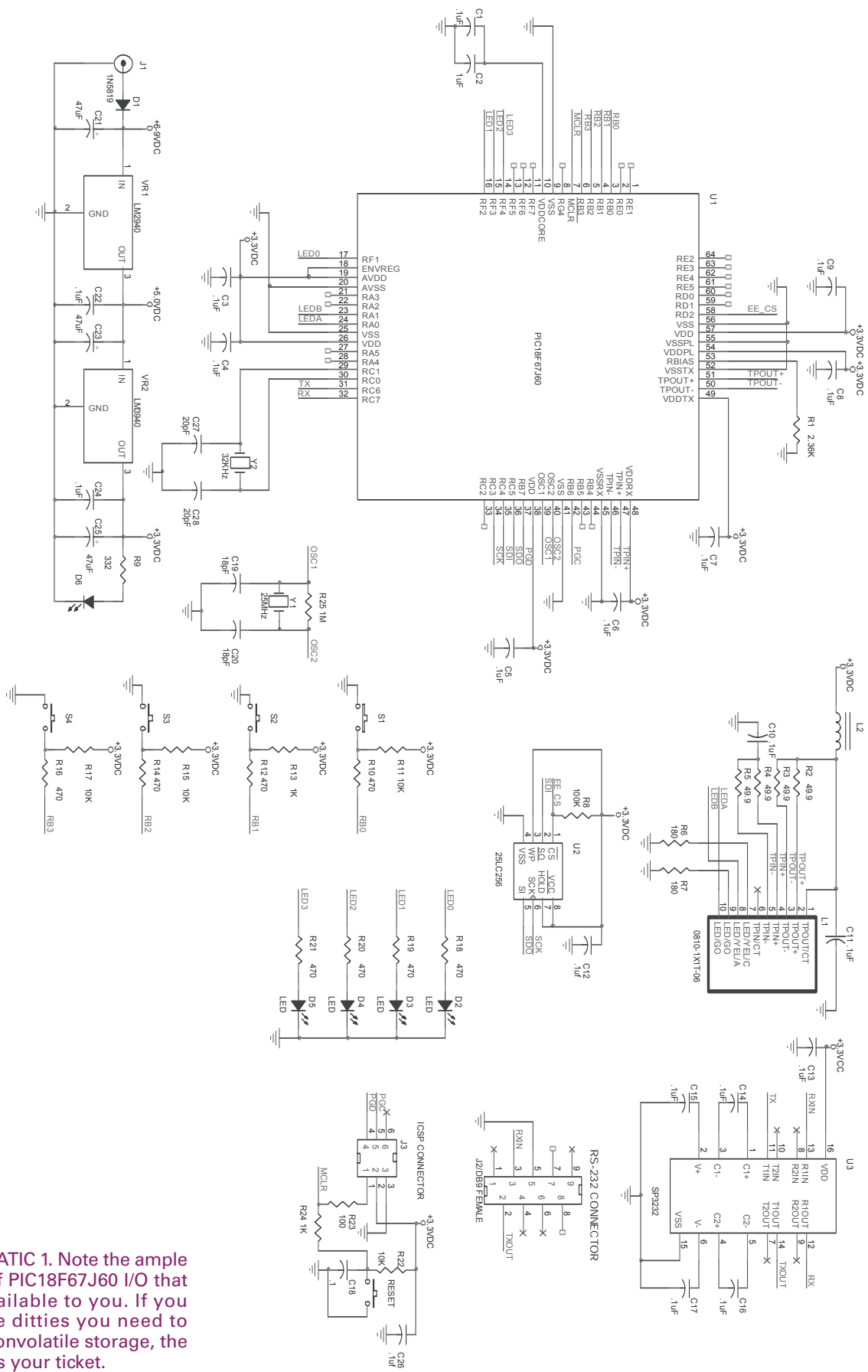
The PIC18F67J60 Ethernet driver firmware I'll provide is constructed with the HI-TECH PICC18 C compiler. As you can see in Schematic 1, the PIC18F67J60 eliminates the need for an SPI interface between the micro-

controller and the Ethernet engine as the Ethernet engine is incorporated into the PIC microcontroller silicon.

Like the ENC28J60, the PIC18F67J60 is a register-based device. If you had a chance to take in one of my ENC28J60 Design Cycle columns, you'll note the absence of the ENC28J60 register and memory access commands in the PIC18F67J60 driver firmware. Memory access commands are not needed when using the PIC18F67J60 as the Ethernet control registers are mapped into the PIC18F67J60's microcontroller data memory area.

With the PIC18F67J60, we no longer need to send access commands to the Ethernet registers and data buffers via the SPI interface. Each PIC18F67J60 register has a unique 12-bit address within the PIC18F67J60's data memory area. The 12-bit register address is composed of a four-bit Bank Pointer (0bBBBBxxxxxxx) and an eight-bit low-order address (0bxxxxAAAAAAAA).

For instance, Bank 15 (0xFxx) contains the analog-to-digital converter result registers (ADRESH/ADRESL) at offsets 0xC4 (0bxxxx11000100) and 0xC3 (0bxxxx11000011), respectively.



■ **SCHEMATIC 1.** Note the ample amount of PIC18F67J60 I/O that is still available to you. If you have little ditties you need to store in nonvolatile storage, the 25LC256 is your ticket.

The 12-bit address for the ADRESH register is 0xFC4, while the ADRESL register is accessed at address 0xFC3. The PIC18F67J60's data memory area is divided into 16 banks with 256 bytes residing in each bank. The highest PIC18F67J60 data memory area address is 0xFFFF, which tells us that the PIC18F67J60 data memory area is composed of 4,096 bytes. If you consider GPR as SRAM, there are actually 3,808 bytes of user SRAM with the rest of the 4,096 bytes being SFR memory space.

It is important to gain access to the most commonly used Special Function Registers (SFRs) and highly-accessed General Purpose Registers (GPRs) within a single instruction cycle. To achieve this goal, the PIC18F67J60 implements an Access Bank, which is a 256-byte area in the PIC18F67J60's data memory space that provides fast access to most of the SFRs in Bank 15 and the lower portion of GPR Bank 0 without having to employ bank switching in firmware. The Ethernet registers EDATA and DIR are located in the Access Bank SFR area. The remaining Ethernet registers we will be working with are located in Bank 14 (0xE0). If you check the ENC28J60 driver code, you'll find that we had to write a special I/O driver to access the ENC28J60's MAC registers. The PIC18F67J60 incorporates a built-in SFR interface that eliminates the need for special MAC I/O firmware. All we have to do is stuff the appropriate MACON SFR to gain access to the MAC register set.

Direct access to the ENC28J60's PHY registers is not available via the ENC28J60's control registers and is only available through the MII (Media Independent Interface). The same holds true for the PIC18F67J60. However, unlike the ENC28J60, the PIC18F67J60 has a built-in MII, which is used to access the PHY registers. PHY access within the context of the PIC18F67J60 is performed via the Mxxxxxx set of PIC18F67J60 SFRs.

The PIC18F67J60 is chock full of registers and registers are made to be dumped and loaded. So, it's pretty obvious that we'll need to code up some rudimentary read and write I/O routines to get at the PIC18F67J60's registers in its data memory area. You're gonna' love this. Here they are:

```
//read Ethernet buffer memory
#define rd_sram() (EDATA)

//write Ethernet buffer memory
#define wr_sram(a) EDATA = a
```

Since there is no SPI interface to deal with, we can simply use the PIC18F67J60's EDATA register, which is the eight-bit portal to the PIC18F67J60's 8KB of Ethernet buffer memory, to transfer bytes to and from the Ethernet buffer memory. Gaining access to the PIC18F67J60's GPRs and SFRs is a simple matter of pointing to the desired register with an address and reading or writing to the address. If you've ever used a PIC internal register in your code, you already know how easy this is to do. All of the GPR and SFR addresses are preconfigured with aliases in the pic18.h and pic18f67j60_driver.h files. The pic18.h file is part of the HI-TECH PICC-18 C compiler while the pic18f67j60_driver.h file belongs to the PIC18F67J60 driver code package.

Now that we know how to access the PIC18F67J60's data memory area and its 8KB of Ethernet buffer memory,

we can embark on some serious PIC18F67J60 driver coding.

CODING THE PIC18F67J60 DRIVER

The next step on our way involves carving up the PIC18F67J60's 8KB Ethernet buffer into transmit and receive areas. We need to determine and specify the extents of the transmit and receive buffer areas within the PIC18F67J60's SRAM buffer. If you take a look back at any of my Ethernet you-build-it Design Cycle columns, you'll see that pointers are used to fence in areas of the Ethernet SRAM buffer space. These pointers are really values stored inside of PIC18F67J60 SFRs. There are also pointers within the PIC18F67J60 SFRs that keep track of bytes that lie within the transmit and receive buffers. This scheme of PIC18F67J60 pointers is very much like the ring buffer pointer architecture used by the RTL8019AS. That's good as it will allow me to directly grab stuff from Fred Eady's field-proven RTL8019AS and ENC28J60 garage stack code and use it to drive our PIC18F67J60.

Let's start by defining our buffer extents.

```
/******
/**   ETHERNET BUFFER DEFINITIONS - ul = unsigned long
/******
#define MAXFRAME      1518
#define TX_BUFFER_SIZE 1518
#define TXSTART      (8192ul - (TX_BUFFER_SIZE + 8ul))
#define RXSTART      0x0000ul
#define RXSTOP       ((TXSTART - 2ul) | 0x0001ul)
#define RXSIZE        (RXSTOP - (RXSTART + 1ul))
```

As you can see in the ETHERNET BUFFER DEFINITIONS, I've decided on a 1,518-byte transmit buffer, which is enough to hold a single maxed out Ethernet frame. Since there are 8KB of total Ethernet buffer area, that leaves just over 6.5KB for the receive buffer area. Considering the packet status overhead, we can buffer four full-sized Ethernet frames into the 6.5K of receive buffer area. Hopefully, we will never leave that many unattended frames in our Ethernet buffer during normal operation. There are only two PIC18F67J60 Ethernet buffer "gotchas" we need to plan for.

The PIC18F67J60 hardware will append seven bytes of transmit status at the end of a transmitted packet in the transmit buffer area. So, we need to leave at least seven bytes of free area between the end of the transmit buffer area and the beginning of the receive buffer area. The other "gotcha" is really a recommendation. In the Microchip documentation, it is hinted that the receive buffer area should start on an even byte boundary and we'll need to address that, as well.

The TX_BUFFER_SIZE and TXSTART definitions define the transmit buffer area. The math within the RXSTART definition takes care of placing the beginning of the receive buffer area at an even byte boundary. RXSTOP is hard-coded to place the end of the receive buffer area at the end of physical SRAM (0xFFFF).

Now we can combine our basic support routines and base definitions to form our PIC18F67J60 initialization routine, which can be seen in Listing 1. The TRISA C statement in Listing 1 sets up the least significant bits of

PIC18F67J60's PORTA as outputs so they can support the Ethernet status LEDs, which are integrated into the Ethernet magnetics. All of the push-buttons are attached to PIC18F67J60's PORTB. So, to service the pushbutton switches, we use the TRISB value of 0xFF to set up all of PORTB's pins as inputs. PORTC supports the RS-232 port, the SPI interface, and the real-time clock. The SPI interface is connected to a 25LC256 EEPROM and we must configure the TRISC bit pattern to set the SPI I/O pin directions (input or output) according to their functions.

The PIC18F67J60's EUSART controller will automatically set the TX and RX pin directions. The EEPROM CS (Chip Select) pin is attached to bit 2 of PORTD. Since the PIC18F67J60 will control the access to the EEPROM, the PORTD TRIS value for bit 2 sets that I/O pin as an output. The least significant bits of PORTF drive the LEDs. So, it stands to reason that we will make the LED driving pins outputs. Of course, you'll need to set the directions of the unused I/O pins if you plan to use them in your project.

Standard microcontrollers need reset time to get their internal act together. The same holds true for the PIC18F67J60, which is basically a standard microcontroller with a big on-chip Ethernet peripheral. Take another look at Listing 1. The PHYRDY bit within the ESTAT register is set when the PIC18F67J60's PHY internals ripen. Nothing should be done to any of the PIC18F67J60's MAC, MII, or PHY registers until after the PHY comes ready. So, following a power-up of the PIC18F67J60, we simply enable the PIC18F67J60's Ethernet electronics by setting the ETHEN bit in the PIC18F67J60's ECON2 register. We then just sit and spin poll the PHYRDY bit and exit the polling loop once the PHYRDY bit is set.

Once we see the PHYRDY bit go logically high, we give the PIC18F67J60

LISTING 1

```
void init_67J60(void)
{
    char x;

    TRISA = 0b11111100;
    TRISB = 0b11111111;
    TRISC = 0b01010111;
    TRISD = 0b11111011;
    TRISF = 0b11100001;
    LED2 = 1;
    LATF = 0xFF;
    //Enable Ethernet
    ETHEN = 1;
    while(!PHYRDY);
    msecs_timer = 0;
    while(msecs_timer < 2);
    //turn off LEDs
    LATF = 0x00;

    RXEN = 0;
    TXRTS = 0;

    packetheader[nextpacket_low] = LOW_BYTE(RXSTART);
    packetheader[nextpacket_high] = HIGH_BYTE(RXSTART);

    ERXSTL = LOW_BYTE(RXSTART);
    ERXSTH = HIGH_BYTE(RXSTART);
    ERXRDPSTL = LOW_BYTE(RXSTOP);
    ERXRDPSTH = HIGH_BYTE(RXSTOP);
    ERXNDL = LOW_BYTE(RXSTOP);
    ERXNDH = HIGH_BYTE(RXSTOP);
    ETXSTL = LOW_BYTE(TXSTART);
    ETXSTH = HIGH_BYTE(TXSTART);

    MACON1 = MACON1_TXPAUS | MACON1_RXPAUS | MACON1 MarxEN;
    NOP();
    //Pad packets to 60 bytes, add CRC, and check Type/Length field
    MACON3 = MACON3_PADCFG0 | MACON3_TXCRCEN | MACON3_FRMLNEN;
    NOP();
    // Allow infinite deferrals if the medium is continuously busy
    // (do not time out a transmission if the half duplex medium is
    // completely saturated with other people's data)
    MACON4 = MACON4_DEFER;
    NOP();

    // Late collisions occur beyond 63 bytes (default for 802.3 spec)
    MACCON2 = 63;
    NOP();

    MAIPGL = 0x12;
    NOP();
    MAIPGH = 0x0C;
    NOP();
    MAMXFLH = LOW_BYTE(MAXFRAME);
    NOP();
    MAMXFLH = HIGH_BYTE(MAXFRAME);
    NOP();

    MAADR1 = macaddrc[0];
    NOP();
    MAADR2 = macaddrc[1];
    NOP();
    MAADR3 = macaddrc[2];
    NOP();
    MAADR4 = macaddrc[3];
    NOP();
    MAADR5 = macaddrc[4];
    NOP();
```

Continued ...

■ **LISTING 1.** There's not much difference between this PIC18F67J60 code and the ENC28J60 code. In fact, the register names are identical across the platforms. That makes for an easy port of the Fred Eady-devised ENC28J60 and RTL8019AS code to the PIC18F67J60.

Listing 1 Continued ...

```
MAADR6 = macaddrc[5];
NOP();

wr_phy(PHCON2, 0x0110);
wr_phy(PHCON1, 0x0000);

wr_phy(PHLCON, 0x0472);

// Set the back-to-back inter-packet gap time to IEEE specified
// requirements. The meaning of the MABBIPG value changes with the duplex
// state, so it must be updated in this function.
// In full duplex, 0x15 represents 9.6us; 0x12 is 9.6us in half duplex

MABBIPG = 0x12;

// Enable packet reception
RXEN = 1;
EIE = 0x00;

printf("\r\n67J60 Initialized\r\n");
}
```

a millisecond or so to stabilize. Note that I turn on all of the LEDs before the PHYRDY polling begins and extinguish them when the PIC18F67J60's PHY comes ready. That's my way of letting you know if the PIC18F67J60's PHY doesn't come up.

Following the completion of the PIC18F67J60's PHY POR (Power On Reset), we must make sure that the PIC18F67J60 is not attempting to transmit or receive. Once the PIC18F67J60's Ethernet MAC and PHY are idle, the PIC18F67J60 initialization routine code establishes the receive buffer boundaries and sets the receive buffer pointers to direct incoming bytes to the beginning of the receive buffer SRAM space.

The PIC18F67J60 will always buffer a packet and indicate in the header of the buffered packet where to go to find the next packet. Here, we must initially load the next packet address information into the packetheader array.

Note the absence of code outlining the end of the transmit buffer area. Transmit buffer area is considered to be any of the 8K SRAM space that is not defined as a receive buffer area. We have already defined the size of the transmit buffer using the TX_START and TX_BUFFER_SIZE. The end of transmit buffer area depends on how much data we push into the buffer. For instance, if we only want to

send 10 bytes, it would be foolish to load the 10 bytes and transmit the entire 1K of buffer holding those 10 little bytes. So, we fill a pointer with the end of our desired transmit buffer.

If we only want to send 10 bytes, then the transmit end buffer pointer will reside at the end of our 10 bytes we want to transmit. Don't worry, we tell the PIC18F67J60 to pad the 10-byte runt packet up to the minimum packet size before transmission by setting the appropriate bits in the MACON3 register. While we're in the MACON3 area, note the absence of the bank select function (banksel(MACON1)) code you would find in the ENC28J60 implementation. Depending on how the HI-TECH PICC-18 C compiler handles the situation, we are either using the Access Bank or directly addressing the register areas within the PIC18F67J60's data memory area.

The values for Non-Back-to-Back Inter-Packet Gap register low byte, MAIPGL, and the Non-Back-to-Back Inter-Packet Gap register high byte, MAIPGH, are taken from the PIC18F67J60 datasheet recommendations. These settings are recommended for use in half duplex mode, which is what we are configuring the PIC18F67J60 to run with.

The final action we take before establishing a unique MAC address for this PIC18F67J60 is to establish the maximum frame size that the

PIC18F67J60's MAC will accept. The 1518 number for MAX_FRAME came about from a maximum data packet size of 1,500 bytes added to 12 bytes of destination and source MAC addresses plus two bytes of type/field information and four bytes of CRC. Once the maximum frame length value is loaded into the MAC, we uniquely identify our hardware by loading a one-of-a-kind hardware address, which is also known as the MAC address.

What follows is the source code that allows us to access the PHY registers. Access to the PHY registers is provided through the MII control registers, which all reside in PIC18F67J60's data memory area. Getting at a PHY

register is easy. The PHY register address is written to MIREGADR. Then, we set the MII read bit in the MICMD register (MICMD_MIIRD), which sets the MISTAT_BUSY bit and begins the PHY register read cycle. The PHY register read completes in 10.24 μ S.

In the meantime, we poll the MISTAT register's busy bit (MISTAT_BUSY) to determine when the PHY read cycle has completed. Once the MISTAT_BUSY bit clears, we clear the MICMD_MIIRD bit. We can then use our standard means of reading the PIC18F67J60's data memory area register spaces to get the 16 bits of PHY register data by way of the MIRD_L and MIRD_H MII read data registers.

Writing to a PHY register is even easier. The address of the PHY register we want to write to is loaded into the MIREGADR MII control register. Data destined for the PHY register is loaded into the MIWRL/MIWRH MII write data pair. The low byte must be loaded first followed by the loading of the high byte, which kicks off the PHY register write cycle. Then, 10.24 μ S later, the PHY write cycle completes. During that time, we are polling the MISTAT_BUSY bit just as we did in the PHY register read operation.

Once the MISTAT_BUSY bit clears, the targeted PHY register has been successfully written. Note the seemingly large number of NOPs in the rd_phy and wr_phy functions. The reason for this is

that per the PIC18F67J60 datasheet, it is not recommended to execute back-to-back operations on MAC and PHY registers. Thus, we insert a NOP (No Operation) instruction between each MAC and PHY register operation.

The MIRD_L and MIRD_H registers are akin to the EDATA register in that data is already present from a previous read operation in these registers and there is no need for us to wait for anything to happen concerning them when we access them to reap the data payload.

Taking up where we left off in Listing 1, the PIC18F67J60 is taken out of loopback mode by setting bit 8 (PHCON2_HLDIS) of the PHCON2 register. The PIC18F67J60 automatically puts itself into loopback mode when half duplex operation is selected. Here's where the PIC18F67J60 shines in comparison to the RTL8019AS. The functions of the PIC18F67J60 status LEDs are easily set up via a PHY register access of the PHLCON register. An external EEPROM or EEPROM emulator routine is necessary to perform LED configuration operations with the RTL8019AS. In our driver, I've configured LEDA to display link status and LEDB to display transmit and receive activity. The LEDB activity flashes are stretched to 40 mS.

The next-to-final act of our PIC18F67J60 initialization routine is to set the back-to-back inter-packet gap time to IEEE specified requirements. For half duplex operation, 0x12, which represents 9.6 μ S, is recommended. The PIC18F67J60 is ready to roll and the lights get turned on with the enabling of packet reception via the ECON1 register.

POLLING FOR PACKETS

The rest of the story involves polling the packet arrival flags or acting on the PIC18F67J60's packet received interrupt. This is where the RTL8019AS Internet function code comes into play. Once a packet is received by the PIC18F67J60, we use the rd_sram function to get the data into the host microcontroller's memory, check to see if the packet is indeed ours, and then proceed to determine if it's ARP, TCP,

ICMP, or UDP in nature, and act accordingly. All of this code already exists in the RTL8019AS garage stack implementation and I've adapted it all to the PIC18F67J60. I also added DHCP functionality to the PIC18F67J60 driver that we initiated in the ENC28J60 driver.

If some of this stuff is still a bit fuzzy, don't worry. I'm not going to leave you hanging. I'll supply the entire compilation of PIC18F67J60 Internet driver/protocol source code

SOURCES

■ **Microchip** — Microchip TCP/IP Stack, PIC18F67J60, MPLAB ICD 2 — www.microchip.com

to you via the *Nuts & Volts* website (www.nutsvolts.com). As always, if you run into a problem incorporating the PIC18F67J60 into your Design Cycle, just fire off an email to me and we'll work it out. **NV**

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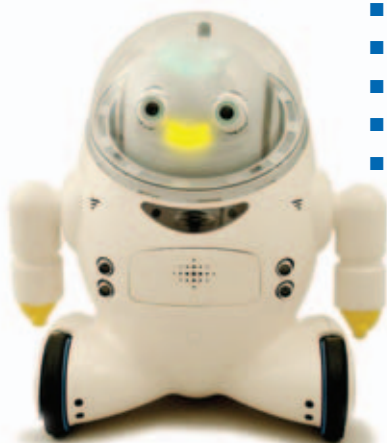
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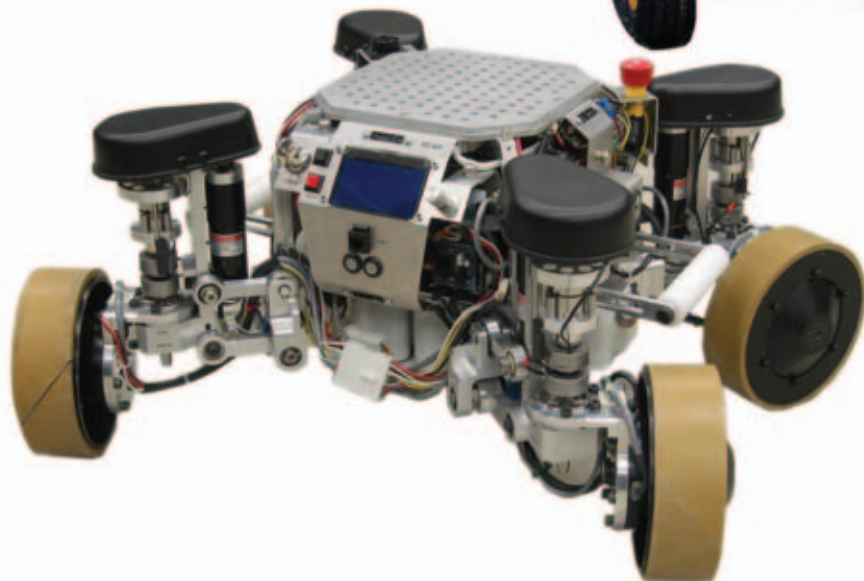
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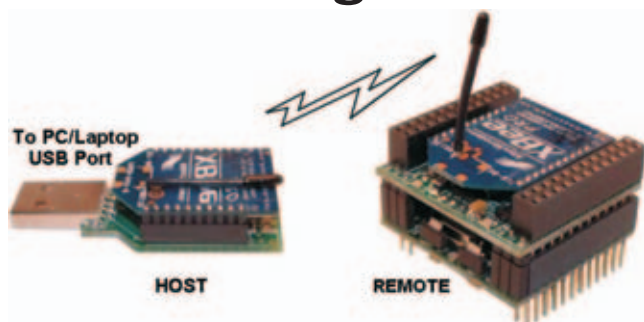
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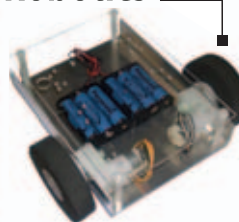


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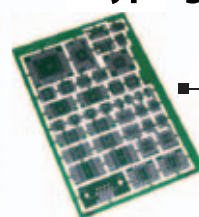
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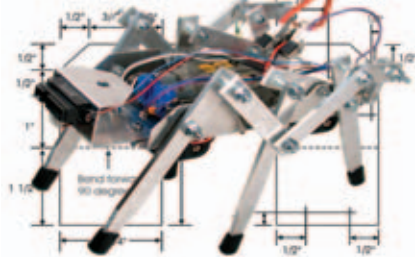
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PERSONAL ROBOTICS

UNDERSTANDING, DESIGNING & CONSTRUCTING ROBOTS & ROBOTIC SYSTEMS

■ BY PHIL DAVIS

PARAMETERS ON THE FLY: Part 1

WHENEVER I BUILD A ROBOT, THERE ARE ALWAYS variables and constants which need to be adjusted to make sure the bot does just what I want it to; the problem is, it's usually a pain to change these. So, how can we make this better? First of all, I want to give a better description of the problem I am referring to and the cumbersome way it currently has to be managed.

PARAMETERS IN YOUR BOT

Not so long ago, I built a mini Sumo robot which didn't have encoders on the wheels — as I suspect most don't — and I had to gauge how long it took the robot to rotate 90 degrees, 180 degrees, and 360 degrees. This required setting a variable which I used to time how long the motors were on. This was a time-consuming thing to do as I had to follow this process:

- Make a change in a variable.

- Compile the program.
- Plug the bot into my computer.
- Download the new code.
- Unplug the bot.
- Start the bot up and observe the effect of the changes.

I have to go through this process every time for every small change to converge on a value which caused the bot to rotate as closely as possible to the desired positions. That's not the only variable, for example, if I want the bot to run in a straight line, I need to adjust another variable, to pause between attacks, yet another variable, and so on.

Another example which was much more complicated was the balancing bot which we talked about a few articles ago. This was more complicated to tune because some of the variables were dependant upon one another; to get it to balance just right, several variables had to be adjusted at the same time.

Now, with the mini Sumo bot, I guess I could have run a cable from the bot to my computer and using debug mode, adjusted the variables on the fly

that way. In actual fact, I would have used the jtag cable and run bot application in symbolic debug mode.

This would have worked just fine with the mini Sumo which sits firmly on the ground and would not be affected by the weight of the cable, but for the balancing bot, this would be a different story. In either case, there may have been timing problems which would have affected the end result, as well.

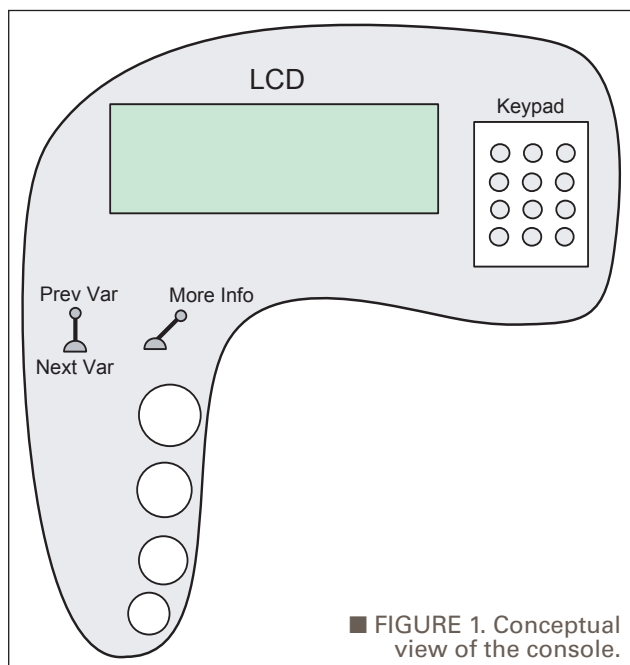
SO, WHAT'S THE SOLUTION?

Well, to define the problem a little better, we need something that:

- Won't physically affect the bot.
- Won't affect the code in some way.
- Allows variables to be changed instantly.
- Allows us to view the old and new values.

My thoughts on this are to build a small handheld console, with an LCD, a keypad, some switches, and an RF interface. Figure 1 shows a conceptual view of this. This might seem like a little overkill, but if I can bypass multiple compilations and change the parameters on the fly, not only will I save lots of time, but I'll have a bot tuned exactly the way I want it.

Most, if not all, of the bots I build are autonomous, so I should make it



■ FIGURE 1. Conceptual view of the console.

clear that this is not an attempt to make a radio controlled bot, but rather a technique to alter variables in real time without interfering with the physical movement of the bot or going through the compile download cycle repeatedly.

The good thing is all the components for this are off-the-shelf and all that is required is integrating them together to create a functional device. Take a look at the block drawing in Figure 2 and the photo in Figure 3.

THE CONSOLE

Let's go through each item in Figure 2 and discuss their features and how they will integrate together to create the console.

- *CPU Board* — This is our standard CPU board which we have been using for some time. It contains an Atmel Mega32, a driver chip (not relevant this time), and an RS-232 chip (perhaps relevant), plus many of the Mega32 pins brought out to headers.

- *LCD* — For the LCD, I am using one from Matrix Orbital, chosen because it talks I²C and this makes it easy for us to tie it into the Mega32.

- *Keypad* — This is also a Matrix Orbital device, designed to attach directly to the LCD. The LCD manages the decoding of the keypad and transmits the characters to the CPU via I²C.

- *RF Device* — This is the "EmbeddedBlue" Bluetooth board offered by Parallax. One of these on the console and one on the bot should allow for an easy established communication link. This board also talks RS-232 out the other end and makes the communication look a little like a cordless RS-232 link — hmmm.

- *Switches* — There are several switches: a power switch, a two-way momentary switch to move vertically

through the data (and perhaps one to move horizontally through the data), and a momentary switch to signal start of data and end of data (enter).

- *Battery* — Here I will use my standard two cell LiPoly battery which will supply around eight volts. I like to use these as they are lightweight and compact for the power output, but 'care and feeding' can be a little difficult.

- *Console Frame* — This is a piece of plastic I had Jerry of Rutherford Robotics cut for me on his laser cutter. I designed it like a game controller since that appears to be an easily-held, two-handed device for entering data.

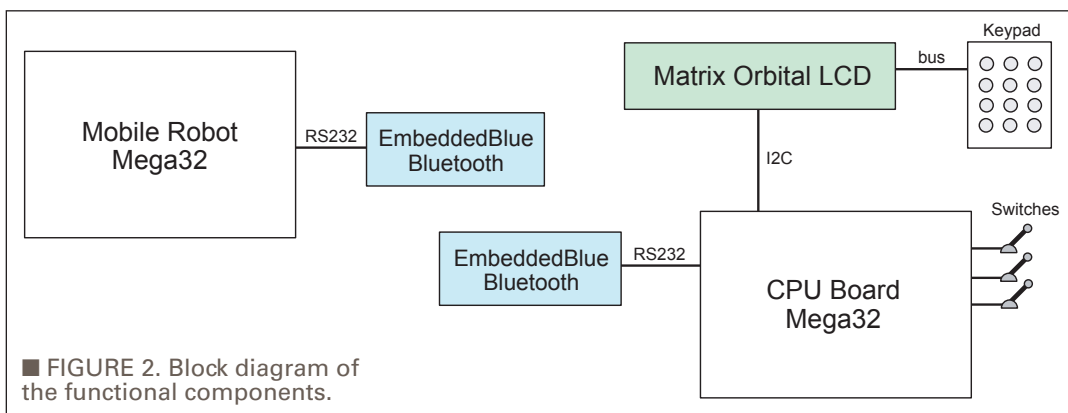
SOFTWARE

There will, of course, be two parts to the software for this device: the code which runs on the console, accepts input data, and sends changes to the bot; and code which runs on the bot, receives these changes, and modifies the required variables.

THE BOT SOFTWARE

On the bot side, we will need a matching EmbeddedBlue attached via RS-232, but first let's consider the software — what needs to happen

■ FIGURE 3. Off-the-shelf components for the console.



■ FIGURE 2. Block diagram of the functional components.

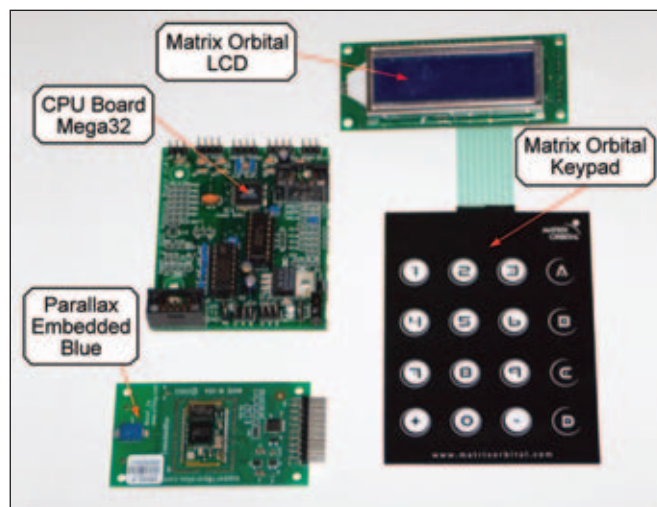
and what may be some of the 'gotchas' of this process.

As a way of illustrating this, we can think of a simple robot with a forward looking distance sensor:

- 1) Runs forward until 'dist' (distance) from an obstacle, then stops.
- 2) Waits 'secs' (seconds) before turning random degrees and running off again.

So, if the bot is running along and 'dist' is equal to 5, when the sensor says the bot is five inches from a wall, for example, the bot will stop. If 'secs' is 2, the bot will wait two seconds, then turn around and run off again.

Our goal here is to allow us to remotely change the values of 'dist' and 'secs.' The first thing we need to describe is what the variables are, what 'type' they are, and what the default value is, among other properties. The best way to do this is to create an array with the elements of



LISTING 1

```
/* parameter variables */
int dist = 5;
int secs = 2;
struct { char name[9];
        char type;
        int iDefault;
        int lowRange;
        int highRange;
        int *var;
} params[2];

/* Initialization of parameter variables */

strcpy(params[0].name, "dist");
params[0].type = 1; // integer
params[0].iDefault = dist;
params[0].var = &dist;

strcpy(params[1].name, "secs");
params[1].type = 1; // integer
params[1].iDefault = secs;
params[1].var = &secs;
```

this array containing the properties of each variable. For now, I am only going to consider integer types, but other types — such as floating and char — should be added (see Listing 1).

That should be enough to describe each variable; a name which should be descriptive; a type, in this case, 1 means an integer; and the default value and the address so we can store the value back into the original variable. Also, there is a fragment of code which is used to initialize the array the first time.

Aside from routines to read the RS-232, we will need a couple of routines to manage the variables. The

first one will be invoked on first contact with the console, i.e., when the console is switched on, it will talk to the bot and request a list of the variables. The function of this routine will be to send the contents of the param array to the console.

The second routine will be invoked whenever the console signals a change of a variable and its job will be to read the variable change from the console (perhaps validate) and then set the variable with the new value.

That should be it for the bot side software! A couple of 'gotchas' to think about might be:

- Does anything else write to a parameter variable or is it read only by the main bot program?
- Are any of the variables dependent upon one another? Do we need to make the changing of multi-word variables atomic, by stopping all other bot activity while updating (is a reset required?)

There are just some things to think about which might cause anomalies during the actual operation of this device. I guess I should also point out that some sort of multitasking or at least interrupt handling will be required to make all of this work. Since I'm in favor of making things easy for myself, I will be using FreeRTOS, a small real time operating system which runs very nicely on the Mega32.

THE CONSOLE SOFTWARE

The console software must complement the bot side of the software just described.

This piece of code has to do quite a bit, a lot of which is mundane, such as reading from the keypad, writing to the LCD managing switch interrupts, and talking to the EmbeddedBlue

board. (By the way, I will be using FreeRTOS here, as well.)

The more interesting functionality is how it manages the parameter changing. The console will have a parameter structure very similar to the one which the bot has, perhaps some additional information (previous value, etc.). The best way to describe the software is to think through how we want the console to operate functionally.

CONSOLE OPERATION

Okay, imagine this ... our bot is on the floor/table running around and we have the console in our hand. We switch on the console and it will immediately establish a communications link with the bot and request a list of all the parameters and their properties.

The bot will package up the parameters and send these to the console which — upon receipt — will indicate 'READY' on the LCD. At this point, let's say we want to change the 'dist' parameter variable from a 5 to a 2. To do this, we would toggle the vertical momentary switch, causing the next parameter in the list to be displayed. Each additional toggle of this switch would advance to the next variable, finally wrapping around to the first.

Depending on available space, the variable name, the default value, and the current value would be displayed on the LCD. Depending on how much information we decide to hold for each variable, we could use the horizontal momentary switch to advance through the additional data.

To change the data, we toggle the 'enter' switch and use the keypad to enter the new value and toggle the enter switch again. This will then transmit the changed value to the bot ... which will assign the new value to the corresponding variable.

Easy right? Well, this is my functional design and hopefully, I will have it up and running for next month's article. In addition, I would like to explore other variable types and expansion to validation of data, so please stay tuned. **NV**

RESOURCES

■ *Matrix Orbital LCD* — www.matrixorbital.com

■ *EmbeddedBlue* — www.parallax.com

■ *FreeRTOS* — www.freertos.org

■ *WinAVR* — <http://winavr.sourceforge.net>

■ *VRstudio* — www.atmel.com/dyn/products/tools_card.asp?tool_id=2725

■ *Rutherford Robotics* — <http://rutherford-robotics.com/laser.html>

IN MEMORIAM *continued*

I read your notice of the death of TJ Byers with deep regret. His column was one of the most enjoyable parts of your magazine for me for years. His work was always informative, well-researched, and easily readable, a tough combination to achieve.

I remember telling myself over the last couple of months that I ought to send him an email thanking him for all his work and to let him know how much I enjoyed his column. Unfortunately, other things kept popping up. I put off writing, and never sent the email. I only hope he knew how much his work was appreciated by all of his readers.

My condolences to all on your staff who knew and worked with him.

**Karl Lunt
Bothell, WA**

My condolences to the staff and readers of *N&V*.

TJ was my personal technical assistant, and when the emails stopped, I wondered why.

His impact to the enthusiast was vast. His wisdom was great.

Thank you, TJ, for all. You will be greatly missed.

**Phil Blake
Wavpro Lighting, Inc.**

Sorry to learn about TJ Byers. His was always the first to read column. He also came up with a couple of circuits I needed. I miss Fuzzball, too.

Thomas Earnest

Sorry to hear about TJ Byers passing. I've read his articles for many years and was impressed with his work.

Anonymous via email

I will certainly miss seeing the byline of the prolific TJ Byers. For me, his name was the most recognizable in your fine publication. I may have seen it as far back as the 50s. What a lot he created, for years and per issue!

On a different note, perhaps the following suggested reader feedback will help avoid a pinned-at-zero output problem.

iNterface Your iPod (Feb 07, p54-56) was just what I was looking for to complete a project requiring analog

memory. However, the suggested electret preamp circuit of Figure 5 will, I am quite sure, output a constant 0 volts DC and AC at the op-amp outputs. The 10K resistors from each of the two op-amp non-inverting inputs should be connected to the positive terminal of the 47 μ F capacitor (AC ground at +2.5V), not DC ground. A drawing error, perhaps.

David Peck

It is with great sadness that I learned of the passing of Mr. Byers. I enjoyed his Q&A column immensely. In fact, I always looked forward to reading his column first when my new *Nuts & Volts* magazine arrived in my mailbox.

Frank Wenk

BOT COLUMN TO THE RESCUE

I just read the Personal Robotics article in the Dec. 2006 *Nuts & Volts* magazine. You can tell your editors that it sold at least one copy that would have otherwise stayed on the shelf.

I teach control systems to engineers, and have wanted to build an inverted pendulum demonstrator, but I couldn't think of a good way to implement the mechanical design — thanks to Phil Davis, that problem is now solved.

I wanted to comment on something in his article. Toward the end, Phil mentions the high friction in the servos, and notes that an Escap motor has sig-

nificantly less friction. I think that you would find that an Escap motor with a gear box would, indeed, have a significant amount of friction, if not as much as the servos that you used. Indeed, any gear train will have high levels of friction, backlash, or both. I have written an article on techniques for coping with friction and backlash; it is at www.wescottdesign.com/articles/Friction/friction.html. Nothing in there is new, I've just summarized the techniques that have found widespread use. Thanks again for the excellent article.

Tim Wescott

KEEP 'CONTROL' COMING

Just a quick note to say that I appreciate the 'Control your World' series by Michael Simpson and hope to see more of his articles in upcoming issues of *N&V*.

**M.Riedel
Plano, TX**

SIMPLE SAWTOOTH SOLUTION

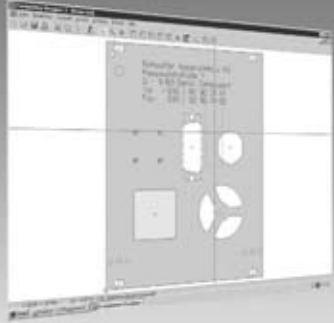
In regards to the February Q&A, a very simple, nicely linear sawtooth generator can be built from any garbage op-amp and a few discrete parts.

The circuit in www.repairfaq.org/sam/sfpidrv1.gif has such a circuit in the lower left (which also does a triangle wave). This was designed for a specific purpose but can easily be modified.

Sam Goldwasser

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All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

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To be considered, all questions should relate to one or more of the following:

- ① Circuit Design
- ② Electronic Theory
- ③ Problem Solving
- ④ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

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>>> QUESTIONS

I have a symphonic SL 2940 VCR that I would like to use as a security component with camera and motion sensor to record for five to 10 minutes as motion is sensed and repeat, if necessary. Audio is not required. Hope somebody has designed a simple circuit for this purpose.

#3071

**Paul Kozlowski
Schertz, TX**

I built an ATMEL-based stepper controller that sent the step commands through four power MOSFETs that connected directly to the coils of a "four volt, 1.2 amp/phase" unipolar stepper. It was an inexpensive motor but it worked great — good torque and speed and started right back if stalled. I bought more of the "same" motor — it had a different label and didn't work at all — stalled, shook, and no torque. I got several different motors from different companies, all with a rating of 4-5 volts at 1-1.2 amps (I'm using a switching supply rated five volts, 3.5 amps) and they all respond differently. None work as well as the first (and cheapest) motor. The MOSFETs have protection diodes and I tried adding diodes to the power lines — no change. I bought a commercial controller with a motor rated 12 volts, .4 amps, which turned out to be a 12-volt version of my original motor, and it worked very well.

The other motors run better with that controller, which has variable current, but still vary in performance. I can't (nor can the motor company) figure out why there is so much variation in output with motors with the same ratings. Is there some way I can get the rated power out of these motors without spending a fortune? Is there another motor rating or spec that I can use to judge these motors?

#3072

**Dan Schwartz
Northbrook, IL**

I am working with the old, very old, MS-Basic Interpreter. It is limited to 16 digits in double-precision mode. If I try to multiply two 15-digit numbers, it slips into "Exponential Notation" mode: example 2.43E+06.

Thus, a 15-digit number *TIMES* another 15-digit number would have a 30-digit product.

Is there a way to convert — in MS-Basic — this "Exponential Notation" into all 30 digits? Also, can the reverse be done in MS-Basic? I would like to work with 100 digit (or more) numbers.

Is there a book that can help me with this problem?

#3073

**Stuart B. Wahlberg
PO Box 1233
Blythe, CA 92225**

I have been told by someone whose judgement and knowledge I normally trust that malware exists that will

write itself into the EEPROM on a hard drive, normally accessible only by the drive manufacturer, used to store such things as a bad sector map, natural-to-logical translation tables, etc. If this is true, are there third-party utilities that can detect and delete such malware? Otherwise, must it be returned to the manufacturer to be "cleaned"?

**#3074 Joseph Richmond
Joppa, MD**

What are the pros and cons for using electrolytic capacitors in a voltage divider circuit to provide about 24 volts AC to a heater cable from the 120 volt AC line?

Is there a possibility of having a capacitor explode from overheating? If so, could that be prevented by stringing several capacitors in parallel to provide for additional heat dissipation?

**#3075 Robert Gotts
Madison, IN**

My old mini van (89 Ford Aerostar) has developed a static whine in the radio. The higher the RPM, the louder the whine. Has anybody come up with a circuit to filter out the noise? What's the best location?

**#3076 Paul Kozlowski
Schertz, TX**

>>>> ANSWERS

[#12067 - December 2006]

I'm having a hard time clearing up excessive static on my AM radio reception, and I want to do time shift recording on my computer. I've purchased an external antenna, but the radio has to be close to this interference source, and even worse, it needs to be connected to it (limiting the distance I can move it). Anywhere in the room is going to have the same problem because of the amount of electronics ranging from fluorescent lights to an office fridge.

Is there an easy way to build a Faraday cage around the radio, so that the interference generated within the room isn't a factor? Then if I use a shielded cable to bring in the external antenna signal from outside and use a ferrite core on the USB cable to the radio, will that stop the RF noise from feeding in through the signal/USB

cables? Unfortunately, I don't understand a lot of the technical aspects of Faraday cages and/or ferrite rings. If there is a good reference for this type of project to help me construct the cage (i.e., materials required as far as composition and structure) and/or select the ferrite ring (diameter, thickness, etc.) then I'd be happy to refer to it if someone could point the way.

I'd hate to spend a lot more time and money chasing a fundamentally flawed hypothesis, so I would appreciate any direction.

#1 Having recently gone through the same difficulty trying to eliminate interference to AM radio reception, I can tell you what did NOT work, what DID work, and why!

WHAT DID NOT WORK AND WHY

You can build a Faraday cage around the radio by wrapping it in aluminum foil. An external antenna can be coupled to the radio by winding a single turn of wire around the case of the radio and hooking the ends to the antenna and ground. You will need to experiment to find out which sides of the case of the radio to wrap the wire around so that it couples to the internal loopstick antenna. Sometimes using two or three turns provides the best coupling once the correct position is found.

Audio will come out of the Faraday cage from the headphone jack on another cable, and here is where the problem is with this system.

As soon as you connect the cable coming from the earphone jack to the computer, you will set up a ground loop and couple the noise source back into the radio rendering the Faraday cage ineffective. Ferrite rings placed on the cable are usually used to eliminate this problem. However, the effectiveness of ferrite rings used as filters on cables decreases with frequency, rendering them almost useless at AM broadcast frequencies. Winding multiple turns of the cable on a larger ferrite ring helped but never provided enough isolation to completely eliminate the interference.

An audio transformer was then tried to break the interference path,

but again with little help. The issue being the capacitance between the windings is sufficient to couple the noise back to the radio.

WHAT DID WORK AND WHY

Find a place where you can get clear reception of the desired station. Use an external antenna if required. It does NOT have to be near the computer. You will see why shortly!

Purchase a wireless FM transmitter. These are readily available today and although primarily designed to work with portable MP3 players, will work with any device with a headphone jack. A typical example is the Genovation Wireless FM Music Transmitter available from **Geeks.com** for \$8.99. www.geeks.com/details.asp?invtid=GENOVATION-307&cat=MP3 There is nothing special about this particular model. Any wireless FM transmitter will work. You should be able to find one at your local electronics or department store for about the same price. Some models will transmit the signal a longer distance.

Connect the FM transmitter to the headphone jack of the AM radio. Back at the computer you will need an FM radio connected to the computer which is used to tune in the rebroadcasted audio from the AM radio/FM wireless transmitter. Before connecting the FM radio to the computer, listen to the rebroadcasted audio on the FM radio and adjust the volume on the AM radio for the best sounding audio on the FM radio. You want it as loud as possible but not so loud that it distorts. Do the same with the FM radio when you connect it to the computer.

FM broadcast radios are much less susceptible to interference, due to the higher frequency used (88 to 108 MHz) and the characteristics of FM modulation. This is why you can place it right along side the computer with no interference. Also, the FM radio is listening to the wireless FM transmitter which is close by providing a much stronger signal than the distant AM radio station.

The real beauty of this system is it allows the AM radio to be placed in the best possible position for clear reception, irrespective of where the

computer is. And since there is no direct connection to the computer, there is no wire to carry the interference from the computer to the AM radio.

This system has saved me a lot of grief when trying to record VLF radio signals and atmospheric effects! Computer interference at VLF frequencies is even worse than at AM broadcast frequencies!

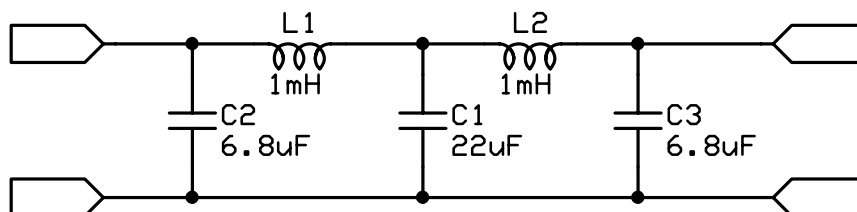
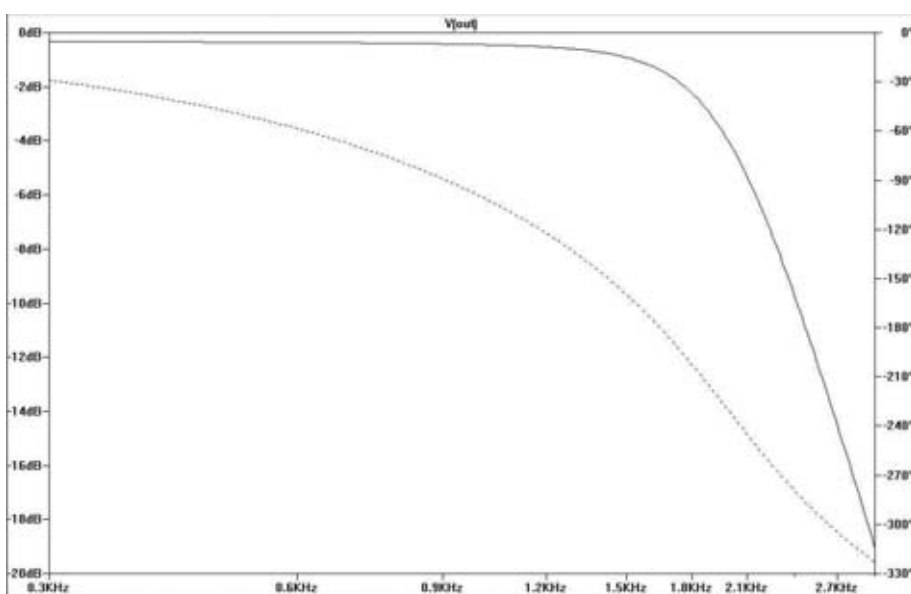
K3PGP - John
via email

#2 The best reference for Mr. Parish is the classic one: *The Radio Amateur's Handbook*, published by the American Radio Relay League (ARRL). This is still the best starting point for learning about the causes and cures for radio interference. Some cures can be applied at the receiver, some have to be applied at the source, depending on the nature and cause of the problem. *The Handbook* discusses the various situations, and describes what to do to deal with each one.

Howard Mark
Suffern, NY

[#2073 - February 2007]

Is there something that can be attached to the wire that goes from my earplug to the external speaker of my police scanner that will diminish the high pitch sounds of fire calls? When an ambulance or fire station is alerted, it is preceded by a series of high pitch,



ear-piercing sounds which I want to eliminate.

This LC filter is a little bulky, but does not require any power and will do a good job of attenuating high frequency noise while allowing voice to pass. The capacitors are nonpolar, radial, and can be mounted on a perf board. The inductor is 1.3 inches in

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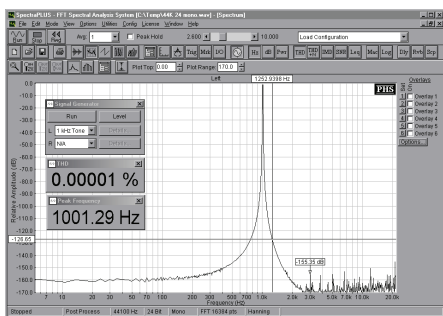
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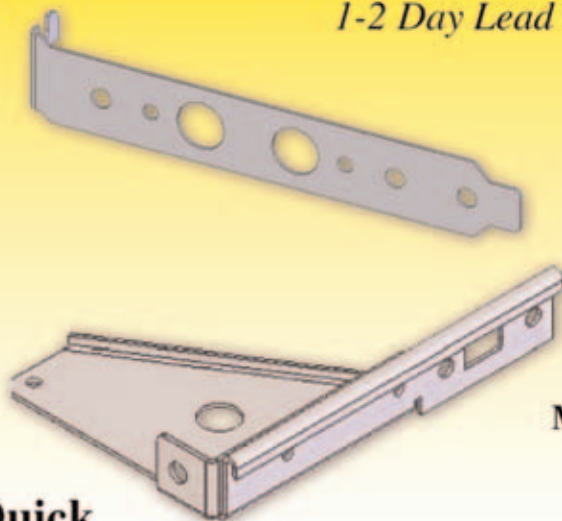
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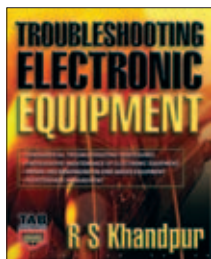
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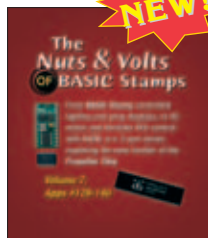
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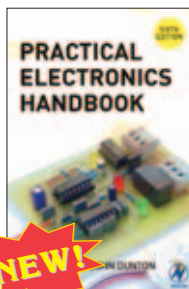


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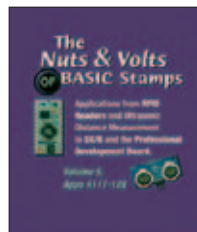
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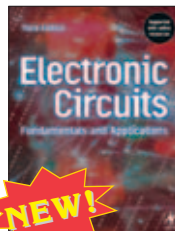
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Nuts & Volts of BASIC Stamps — Volume 6 includes articles #117-128, written for 2005. Article topics consist of RFID Readers and Ultrasonic Measurement, SX/B and the Professional Development Board, the advanced MIDI receiver, programming the SX microcontroller in BASIC, mastering the MCI4489 display driver, and more! The *Nuts & Volts of BASIC Stamps* books are a favorite Parallax technical pick and are a tremendous technical resource for all PBASIC programming projects. **\$14.95**



Electronic Circuits — Fundamentals & Applications: Third Edition by Mike Tooley

In *Electronic Circuits*, Mike Tooley provides all the essential information required to get to grips with the fundamentals of electronics, detailing the underpinning knowledge necessary to appreciate the operation of a wide range of electronic circuits, including amplifiers, logic circuits, power supplies, and oscillators. The third edition now offers an even more extensive range of topics, with extended coverage of practical areas such as circuit construction and fault finding, and new topics including circuit simulation, electronic CAD, and a brand new chapter devoted to the PIC microcontroller. **\$34.95**



Troubleshooting and Repairing Consumer Electronics Without a Schematic

by Homer L. Davidson

In this completely updated new edition of his best-selling guide, Homer Davidson gives you hands-on illustrated guidance on how to troubleshoot and repair a wide range of electronic products — when you can't get your hands on the schematic diagrams. One of the most respected names in consumer electronics, Davidson shows you how to diagnose and solve circuit and mechanical problems in car stereos, cassette players, CD players, VCRs, TVs, and TV/VCR combos, DVD players, power supplies, remote controls, and more. **\$34.95**



Electronic Games for the Evil Genius

by Thomas Petruzzellis

You can have a wicked amount of fun on your way to becoming a game master! In *Electronic Games for the Evil Genius*, popular how-to author Tom Petruzzellis gives you everything you need to build 35 exciting games and gadgets. You get complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin. Packed with fun projects that you'll love to build and play with, this guide develops game expertise one simple step and project at a time. **\$24.95**



PROJECTS

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by Jerri Ledford

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Here is an awesome next-generation collection of LEGO MINDSTORMS projects that enables you to build and program a real working robot in just 30 minutes! New technologies and expanded sensor capabilities make it easier than ever to add a level of sophistication to robotic and architectural creations. The book explains the all-new NXT intelligent brick ... the interactive servo motors with rotation sensors that align speed for precise control ... the ultrasonic sensor that allows robots to "see" by responding to movement ... the improved light and touch sensors that let robots detect color and feel ... and much more. **\$24.95**



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Take This Stuff and Hack It! by Dave Prochnow

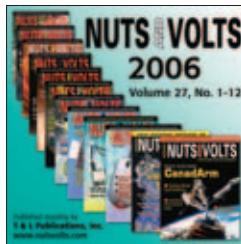
Transform common household items into really cool stuff. You don't need to be an electronics genius to get started turning everyday items into high-performing wonders. With how-to guru Dave Prochnow's step-by-step directions and fully illustrated plans, even beginners can hack their way to a high-tech home, cooler toys, and less yard work. Certain to fire your imagination and start you plotting new, original, and even more creative wonders you can make from ordinary household items, *Take This Stuff and Hack It!* is the perfect gift for your inner inventor. **\$27.95**



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Here's some good news for Nuts & Volts readers! Along with all 24 issues of Nuts & Volts from the 2004 and 2005 calendar years, the 2006 issues are now available, as well. These CDs include all of Volumes 25, 26, and 27, issues 1-12, for a total of 36 issues (12 on each CD). These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **\$24.95 – Buy 2 or more at \$19.95 each**



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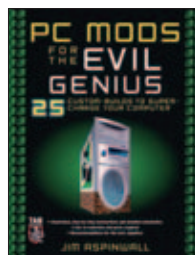
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HOME COMPUTERS

PC Mods for the Evil Genius by Jim Aspinwall

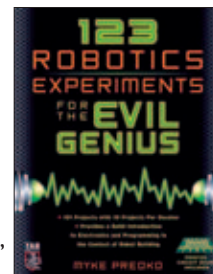
If you yearn for the coolest, most crazed 'puter around, *PC Mods for the Evil Genius* is the key to the kingdom! This book shows you how to supercharge your PC and create a jaw-dropping system that cannot be purchased off any shelf, anywhere! You get complete, easy-to-follow plans, clear diagrams and schematics, and lists of parts and tools, so you know what's needed before you begin. **\$24.95**



ROBOTICS

123 Robotics Experiments for the Evil Genius by Myke Predko

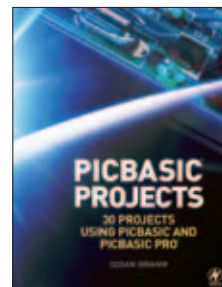
If you enjoy tinkering in your workshop, you'll have hours of fun working through the 123 experiments found in this innovative project book. These exciting experiments also provide a solid grounding in robotics, electronics, and programming. Each one builds on the skills acquired in those before it so you develop a hands-on, nuts-and-bolts understanding of robotics — from the ground up. **\$25.00**



MICROCONTROLLERS

PIC Basic Projects by Dogan Ibrahim

Covering the PIC BASIC and PIC BASIC PRO compilers, *PIC Basic Projects* provides an easy-to-use toolkit for developing applications with PIC BASIC. Numerous simple projects give clear and concrete examples of how PIC BASIC can be used to develop electronics applications, while larger and more advanced projects describe program operation in detail and give useful insights into developing more involved microcontroller applications. **\$29.95**



Programming the PIC Microcontroller with MBASIC by Jack Smith

No microcontroller is of any use without software to make it perform useful functions. This comprehensive reference focuses on designing with Microchip's mid-range PIC line using MBASIC, a powerful but easy to learn programming language. It illustrates MBASIC's abilities through a series of design examples, beginning with simple PIC-based projects and proceeding through more advanced designs. **\$59.95**



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IN THE SPOTLIGHT

An Interview with Woolf Kanter of All Electronics

by Marvin Mallon

If you are looking for a wide variety of hobby and experimenter supplies, you just might want to do business with All Electronics Corp. This small, family owned and operated establishment is located in Van Nuys, CA and has been operating for nearly 15 years at their present location. Two brothers, Alan and Woolf Kanter, supervise a team of 30 employees who boast of fast turn-around times for all orders placed by mail, fax, or online. Their 18,000 square foot facility handles a lot of walk-in trade, as well as serving as headquarters for all of their mail order business. Additionally, they own a 15,000 sq ft warehouse in downtown Los Angeles.

Alan — the older of the two by one year — is an ex-musician who still surfs at age 60. Woolf's pastime activities run to cooking and physical fitness. He attended Cal State Hayward, a northern California state-run college where he studied computer science back in the '70s.

Their father started the business in 1967 selling surplus goods out of a

warehouse in Los Angeles. When Alan decided that the musician's life might not be for him, he joined his father working part time. Soon after, Woolf gave up his job driving a taxi in San Francisco and went to work with his father and brother in the business. Together, they began a mail order business in the early '80s and have teamed up to run it successfully ever since.

The advent of the Internet allowed them to expand their operation considerably and they presently serve more than 45,000 customers. The online portion of their sales accounts for nearly 80 percent of their transactions.

Power supplies, CCD image sensors, and mini-gearhead motors are only a small representation of the numerous electronic items available from them. As their website at **www.allelectronics.com** indicates, the extensive list of available devices runs alphabetically from AC Line cords to Wiring Nuts.

When asked about the diversity of inventory, Woolf replied, "We sell loads of small DC motors, LEDs, and LCD displays. We have a wide variety of electronic parts and supplies, some very unique items. We do not specialize in any particular item but have a wide variety of electronic parts."

It's not an exaggeration when he says that they offer many unique items. To quote one entry on their website of a Laser Parking Device with Motion Sensor, "A peculiar, yet oddly practical device to take the guesswork out of parking your vehicle in the garage. Some people do this the old fashioned way

with a tennis ball hanging on a rope. The adjustable laser pointer mounted on the wall or ceiling of the garage is activated when the car enters the garage. The laser beam, set to project a point of light on the car's dashboard or hood, lets you know when the car is where you want it. The laser shuts off automatically after a short time." You've just got to have one of those, right?

Woolf goes on to say, "We add dozens of new parts (some of them industrial surplus) every week. We publish a mail order catalog (96 pages) every eight weeks and update our website daily." The catalog he describes is also available in PDF format and can be downloaded directly from their website. Of course, you'll need to install Acrobat Reader in order to print it out, but you're sure to use half a cartridge of ink doing so. Best to fill out the free order form and wait for snail mail to drop off your copy.

While many distributors around the country offer a host of competitive devices, you might consider putting All Electronics high on your list of vendors to do business with. Their four decades of serving both the hobbyist and serious experimenter speaks well of their reliability. **NV**



Alan (left) and Woolf Kanter (right), partners at All Electronics Corp.

CONTACT ALL ELECTRONICS

14928 Oxnard St.
Van Nuys, CA 91411

A toll-free number for sales is **800-826-5432**. Orders can be taken online at **www.allelectronics.com**



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**Stepper Motor Controllers 2 Phase Microstepping Stepper Motor Driver (Bi-polar & Unipolar Motors)**

Part #:	Dimensions:	MicroStep:	Price:
XCW220	100mm x 61mm x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	\$39.95
CW220	99mm x 65mm x 30mm	1/2(400), 1/8(1600)	\$49.95
CW230	115mm x 72mm x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	\$59.95
CW250	140mm x 94mm x 45mm	1(200), 1/2(400), 1/8(1600)	\$69.95
CW860	147mm x 97mm x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 1/128(25600), 1/5(10000), 1/10(2000), 1/25(5000), 1/50(10000), 1/125(25000), 1/250(50000)	\$119.95

Protek**Protek 2.0 & 2.9GHz Field Strength Analyzers**

- Frequency Range : 100KHz ~ 2900MHz (2060MHz for 3201N)
- WFM/NFM/AM/SSB modulated signals may be measured.
- Sweep Trigger Mode: Free Run, Single Run, Continuous Wave, Squelch Run
- Sweep Speed: 500 to 2000msec
- PLL tuning system for precise frequency measurement and tuning
- Built-in Frequency Counter
- RS232 interface

3290N

**New
Rev. Now
Available**Item#s **3290N & 3201N**[Details at Web Site](#)> [Test Equipment](#) > [RF Test Equipment](#)**Special****\$1899.00 (for 3290N)****\$1374.00 (for 3201N)****Outdoor Color Speed Dome Camera**

- 1/4" SONY Exview CCD
- 768(H) x 494(V) effective pixels
- Horizontal Resolution: 480TV lines
- Up to 80 preset points
- Line scanning
- Continuous 360° horizontal rotation
- Vertical rotation: 0-100°
- RS485 control interface
- Min. Illumination: 0.1Lux (color) / 0.001Lux (B&W)

Item# **VC-EX861****\$899.00**[Details at Web Site](#)**Shown with optional wall mount**> [Miniature Cameras\(Board,Bullet,Mini's, B/W, Color\)](#)**480
TV Lines
Resolution**

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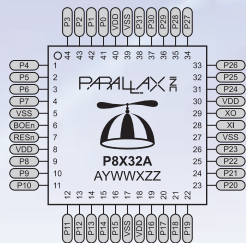
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\$149.95 #32300

Introducing Parallax's first custom silicon chip, designed from the transistor-level up for speed, flexibility, and pure FUN!

The Propeller is a multi-processing chip with eight 32-bit processors (cogs) and a shared memory which includes 32KB of RAM and 32KB of ROM with a font, math tables, and SpinTM interpreter. The Propeller can be programmed in high-level Spin, assembly language, or a combination of the two for the perfect blend of simplicity and performance.

The **Propeller Starter Kit (#32300; \$149.95)** includes everything you need to get started with the Propeller microcontroller, including the Propeller Demo Board, the Propeller Manual, software on CD, a power supply, and a USB cable. The Propeller Demo Board includes a built-in Propeller (P8X32A-Q44), EEPROM and 5 MHz crystal pre-wired to connectors for interfacing to devices such as a mouse, keyboard, TV or VGA monitor and speakers. *Propeller Accessories Kit; also available, not pictured; #32311; \$99.95.*



Order the Propeller Starter Kit (#32300; \$149.95) at www.parallax.com or call the Parallax Sales Department toll-free 888-512-1024 (Mon-Fri, 7am-5pm, PT).

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